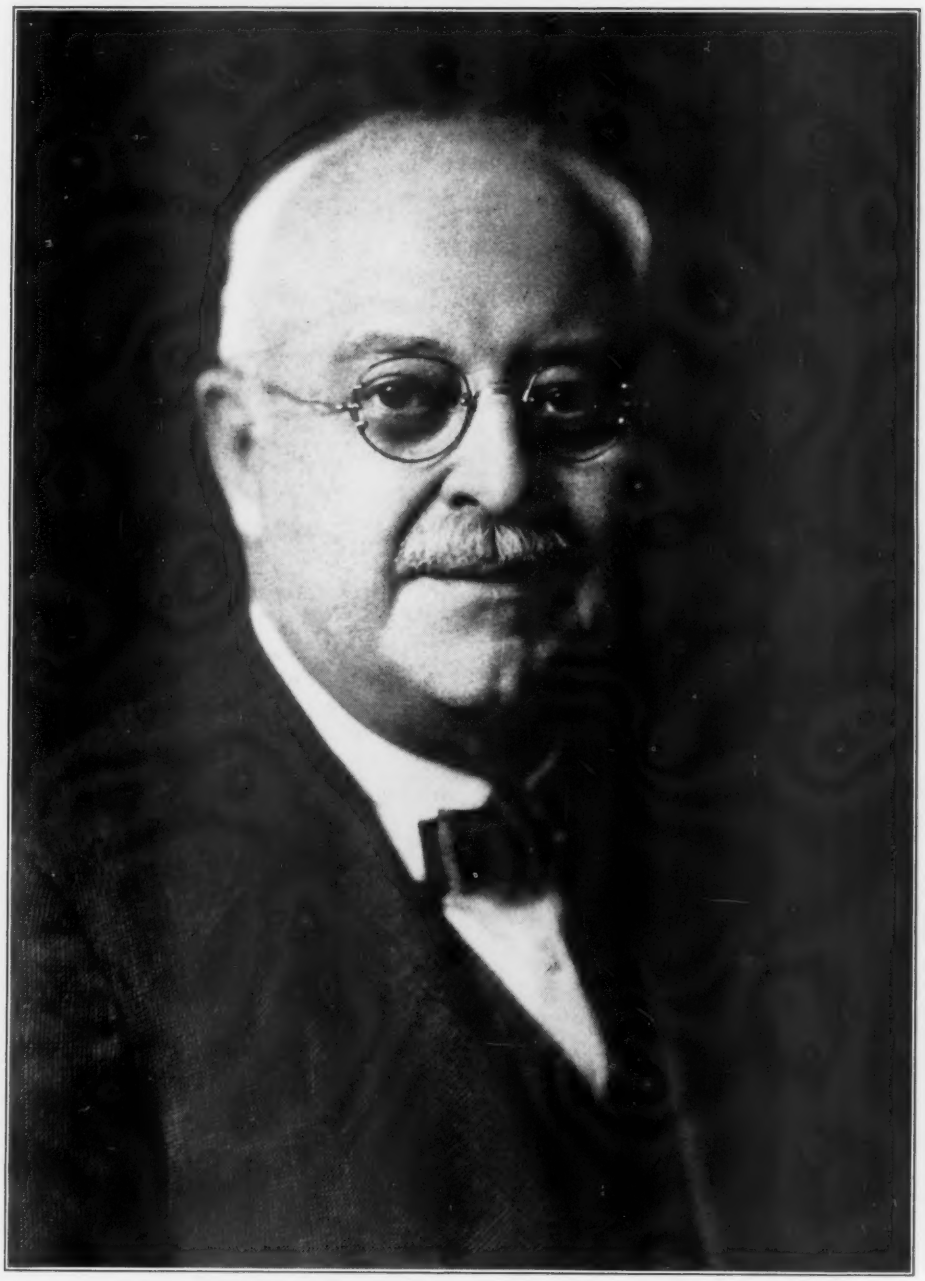
THE BULLETIN

OF THE

AMERICAN CERAMIC SOCIETY

Volume 19 FEBRUARY, 1940 Number 2



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Volume 19 February, 1940 Number 2

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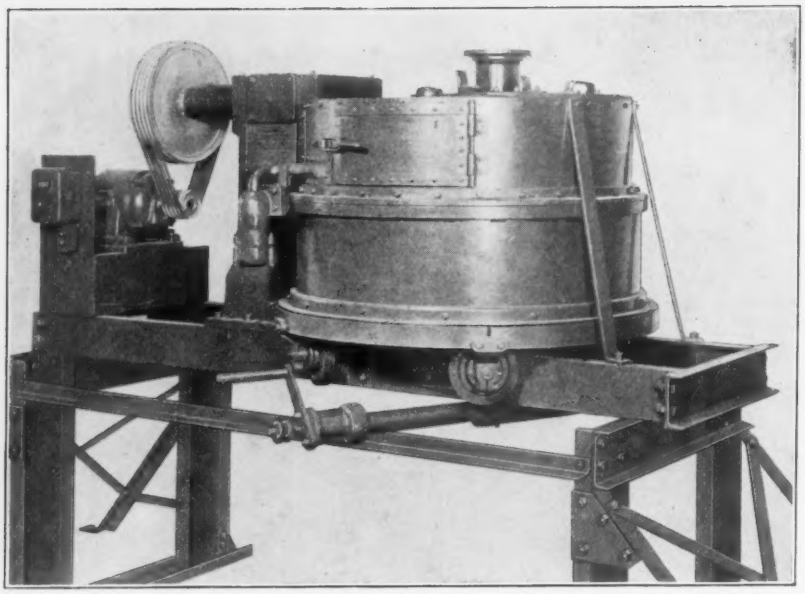

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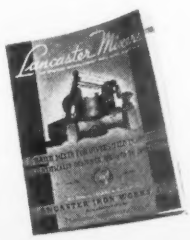

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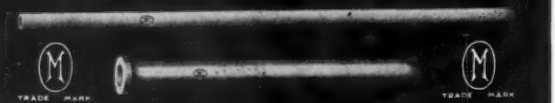

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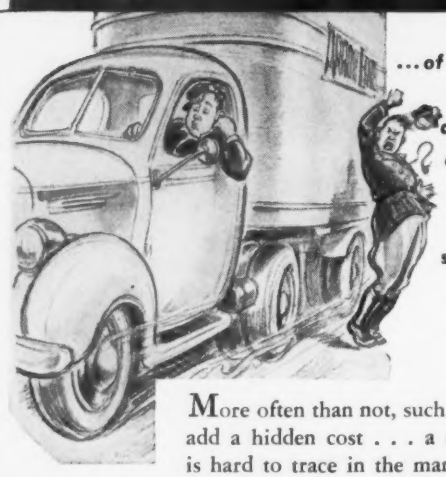

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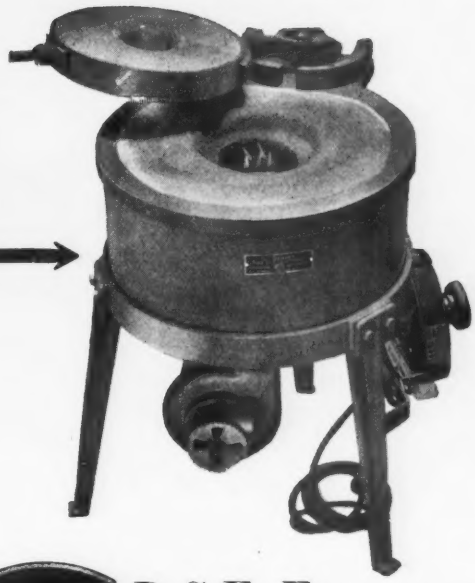

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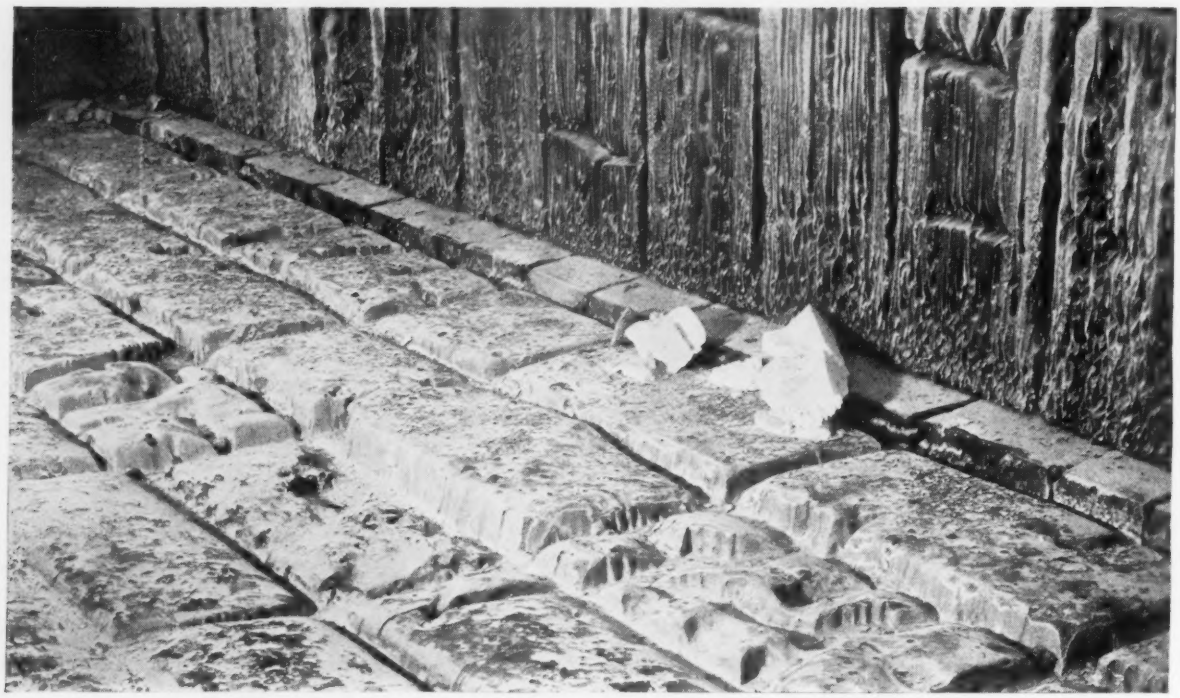

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Volume 19 **FEBRUARY, 1940** **Number 2**

PAPERS

USE OF ORGANIC DISPERSING AGENTS IN CASTING SLIPS*

By Ira E. Sproat, C. C. Treischel, and E. W. Emrich

Abstract

The effect of clay deflocculant vs. sodium silicate on the physical properties of casting slips of typical whiteware bodies has been determined. Similar data on thirty-nine commercial castings slips are given, and thixotropy and the effect of temperature are also discussed.

I. Preparation of Samples

An 8000-gram batch (dry weight) was used for the tests described in this investigation. Enough hot water (usually about 3400 cc.) to give the required specific gravity was first poured into the mixing bowl of a ten-quart Read "Mixonette," and sufficient electrolyte was added to produce a thick slip. The clays, ground to 20-mesh and finer, were added and thoroughly dispersed, the nonplastics were added, and the entire batch was blunged for two hours. The resulting slip was screened through an 80-mesh screen and was stored in a closed jar. After determining the water content, enough slip to contain 800 grams of dry body was weighed into glass fruit jars. The original batch of 8000 grams made about nine 800-gram batches. Water and electrolyte were added to the batches; the mixture was shaken thoroughly, left standing overnight, shaken for five hours the next day, and twenty-four hours after it was put into the glass fruit jars it was tested.

Table I

Changes in Slip During Test Period

Electrolyte (%)	Flow (sec.)		pH		Specific gravity	
	New	24 hr.	New	24 hr.	New	24 hr.
0.150	81	42	5.75	5.59	1.73	1.75
0.175	38	25	5.88	5.69		
0.200	40	22	5.93	5.74		
0.225	35	21	5.93	5.78		
0.250	26	21	6.05	5.82		

Note: If a high-speed mixer is used, the reverse might be true, i.e., the slip will thicken on standing for 24 hours because the high speed of the mixer produces a greater amount of mechanical dispersion.

Because the slips stored for longer periods of time showed but little change, the 24-hour period was chosen.

This method of preparing the samples for testing eliminates most of the errors that occur in handling small laboratory batches and permits a study of slips at maximum densities.

II. Tests

(1) Viscosity

The viscosity tests were made by determining the time for 210 cc. of slip to run through a $^{7}/_{32}$-inch orifice. To give a freer flow to the slip, the top of the efflux viscosimeter was removed, and a constant head was maintained by keeping the slip at the same level.

(2) Hydrogen-Ion Determinations

A Beckman pH meter was used for the pH determinations, which were made directly on the slips and not on the filtrates. This method seems to give more consistent results than the usual colorimetric method.

(3) Specific Gravity

A 250-cc. volumetric flask was filled with the slip, the top scraped off, and weighed.

All slips were tested at a temperature of 27° to 30°C. unless otherwise specified.

(4) Thickening

Because all casting slips have a tendency to thicken, the need for a standard test for the thickening rate is apparent.

* Presented at the Autumn Meeting, White Wares Division, American Ceramic Society, Bedford Springs, Pa., September 16 and 17, 1938. Revised paper received April 6, 1939.

For all practical purposes, a thixotropic slip[1] may be defined as one that thickens on standing a short time after being agitated or one that appears "mushy." Some clays do not disperse readily and have a decided "mushy" appearance even at the minimum viscosity point; it is not known whether this is a true thixotropic condition. Tests on the Stormer viscosimeter[2] seem to give indications of the degree of thickening.

The number of revolutions per minute made by the cylinder, which was immersed in the thoroughly agitated slip, was determined. A 15-second reading usually is sufficient; this number multiplied by four gives the number of revolutions per minute.

After the slip stood in the test cup without agitation, readings were taken successively at the end of periods of two, three, five, and five minutes; thus the slip was undisturbed in the test cup a total of 15 minutes, except for the slow rotation of the cylinder during the five testing periods.

(5) Rate of Casting

The rate at which slip will produce ware of desired thickness is important in valuating a dispersing agent. Consistent results were obtained by weighing small test pieces made by casting for 30 minutes. This wet weight of the test piece indicates the casting rate. The average of weights of three test pieces gives consistent results.

III. Commercial Casting Slips

A number of commercial slips were tested, and the results are given in Table II. All of the slips used in this series of tests were found to be satisfactory under factory conditions at the time they were obtained. These data show that the properties of the thirty-nine commercial slips vary greatly even in bodies of the same type. About the only conclusion that may be drawn from this set of tests is that the bodies for general ware and artware have a lower specific gravity than those for vitreous china and sanitary ware, and the electrical porcelain bodies have a higher specific gravity.

Each body and each factory apparently have individual casting problems. The development of an organic dispersing agent which will successfully disperse all types of bodies under varying conditions is difficult.

IV. All-Kaolin Body

The results obtained with clay deflocculant No. 2[3] in this type of body are described by Hedquist, Gould, and Wilson,[4] who state, "In many ways this deflocculant is quite remarkable. The ware releases quickly from the molds, and the resultant cast is very plastic, facilitating trimming and sticking on handles or spouts." A typical viscosity curve is given.[5]

V. General Ware Bodies

The compositions of the bodies for general ware are given in Table III, and the viscosity results are plotted in Figs. 1, 2, 3, and 4. Inasmuch as all tests were made on bodies that were not washed before adding the electrolyte, none of the soluble salts present in the raw

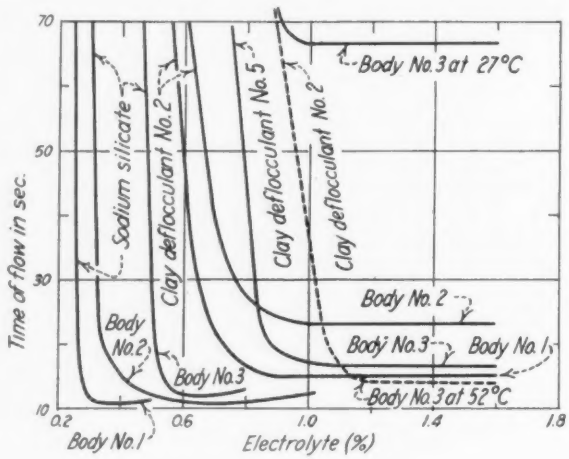

FIG. 1.

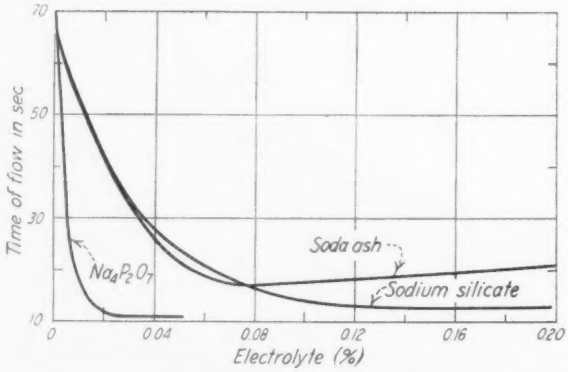

FIG. 2.—General ware body No. 3 dispersed with 1% clay deflocculant No. 2 plus varying amounts of soda ash, sodium silicate, and $Na_4P_2O_7$.

[1] (*a*) H. B. Weiser, Inorganic Colloid Chemistry, Vol. III, p. 373. John Wiley & Sons, Inc., New York, N. Y.
(*b*) E. A. Hauser and C. E. Reed, "Studies in Thixotropy," *Jour. Phys. Chem.*, **40** [9] 1169 (1936).
(*c*) H. Freundlich, "Actualites Scientifiques et Industrielles," The Colloidal State: I, Thixotropy, No. 267. Hermann & Cie., Paris, 1935.

[2] Physical and Chemical Examination of Paints, Varnishes, Lacquers, and Colors. Institute of Paint and Varnish Research, Washington, D. C. The viscosimeter may be purchased from Eimer and Amend, New York, N. Y.

[3] Clay deflocculant No. 2 is an organic dispersing agent with ammonia as the base; clay deflocculant No. 5 is the same except that in addition it contains a small percentage of a soda salt. The standard solution contains 17.0% solids; 1 gal. weighs 8.75 lb.; specific gravity, 1.05; 1 gal. contains 1.4875 lb. of solids; the pH of No. 2 is 9.98 and that of No. 5, 10.25.

[4] A. J. Hedquist, R. E. Gould, and E. W. Wilson, "Casting All-Kaolin Bodies of True Porcelain and China Types, V," *Jour. Amer. Ceram. Soc.*, **20** [6] 197–202 (1937).

[5] *Ibid.*, p. 199.

TABLE II

COMMERCIAL BODIES

Body No.	Flow (sec.)	Sp. gr.	Water (%)	pH	Temp. (°C.)	No. of revolutions on Stormer viscosimeter (minutes) 0	2	5	10	15
				General ware bodies						
1	14	1.825	27.1	7.80	27					
2	12	1.710	32.6	7.00	28					
3	15	1.790	28.8	8.10	28					
4	26	1.775	29.4	7.45	28					
5	33	1.835	26.5	7.45	27					
6	52	1.753	30.3	7.85	28					
7	21	1.782	28.9	8.10	28	33	32	28	12	10
8	15	1.750	30.7	7.80	28	60	35	20	9	5
9	17	1.857	25.5	8.40	28	34	35	35	35	35
10	63	1.807	28.3	8.30	28					
11	9	1.690	34.2	8.20	27	212	209	206	204	200
12	12	1.715	33.1	8.00	28	78	52	36	20	12
				Artware bodies						
13	9	1.645	37.5	7.75	28					
14	14	1.712	32.0	6.20	28					
15	10	1.580	41.5	7.60	28	18	5	3	1	1
16	9	1.540	43.7	7.50	28	30	12	6	3	1
17	11	1.777	29.4	8.60	28	116	110	104	99	96
18	8	1.503	45.5	6.50	28	384	372	367	365	360
19	63	1.885	24.5	7.60	28	20	14	12	10	8
20	9	1.728	32.2	10.40	27	224	219	216	214	214
				Vitreous china bodies						
21	27	1.758	31.6	8.40	27	44	36	32	28	26
22	36	1.828	27.0	8.30	27	28	23	18	15	14
23	15	1.823	27.0	8.00	28	84	81	77	73	70
24	58	1.858	25.4	7.60	28					
25	36	1.797	28.7	8.30	28					
				Sanitary ware bodies						
26	14	1.782	29.1	8.00	28					
27	31	1.822	27.0	6.95	28					
28	22	1.811	27.8	6.20	28	44	36	28	24	20
29	35	1.808	28.1	7.90	27	33	21	16	4	1
30	20	1.810	27.9	9.10	27	54	46	40	32	28
31	22	1.832	26.8	7.80	28	52	40	30	24	20
32	17	1.830	26.7	8.20	28					
				Electrical porcelain bodies						
33	49	1.840	26.0	6.90	27	21	17	13	11	8
34	103	1.900	23.4	8.20	27	14	13	12	11	10
35	55	1.800	27.9	6.50	28					
36	19	1.792	28.7	7.85	28					
37	76	1.907	23.2	7.70	29					
38	50	1.908	23.0	8.10	28					
39	30	1.858	25.4	7.65	28					

materials was removed. Tap water with a pH of about 7.4 was used in all tests except when otherwise noted. The percentage of electrolyte is figured on the dry weight of the body and represents the standard solutions of "S" brand sodium silicate and clay deflocculant and not on the dry solid content of the electrolyte.

(1) Bodies Nos. 1, 2, and 3

These bodies are grouped together because they have the same percentage composition, the only difference being in the type of ball clay used. All slips were made up with about 30.9% water on the wet basis; their specific gravity was 1.75.

Figure 1 shows that at about 30°C. (86°F.) maximum deflocculation of body No. 1 is produced with 0.35% of sodium silicate or 0.9% clay deflocculant No. 2 and 0.6% sodium silicate or 1.0% clay deflocculant No. 2 for bodies Nos. 2 and 3. These percentages, however, are figured on the solution as it is shipped rather than on the dry weight of the electrolyte. On the dry basis, the percentage of clay deflocculant No. 2 necessary to produce maximum deflocculation will be close to that of sodium silicate because this deflocculant solution contains only 17% solids, whereas "S" brand sodium silicate contains 31% solids.

At the temperature of these tests, 27° to 30°C., clay deflocculant No. 2 does not decrease the viscosity as much as sodium silicate, particularly in body No. 3, which contains No. 5 ball clay; this is equally true of other ball clays of the same type. The reason for this difference cannot be explained at the present time. With body No. 3, however, maximum dispersion is obtained with 1.0% clay deflocculant No. 2, which gives

TABLE III

COMPOSITIONS OF GENERAL WARE BODIES

	Body No.				
	1 (%)	2 (%)	3 (%)	5 (%)	6 (%)
"Jasper" flint	35.0	35.0	35.0	35.0	19.0
Maine feldspar	12.0	12.0	12.0	12.0	
N. C. feldspar A-2					3.0
"Cherokee" Ga. kaolin	21.0	21.0	21.0	21.0	13.0
Ky.-Tenn. Clay Co. No. 4 ball clay	32.0	16.0	16.0	12.0	16.0
Bell dark ball clay		16.0			16.0
Bell Dresden ball clay				10.0	
Spinks Challenger and Champion				10.0	
Harris N. C. kaolin					10.0
Loomis talc					6.0
H. S. "Pyrax" pyrophyllite					16.0
Imported whiting					1.0
Ky. Clay Mining Co. No. 5 ball clay			16.0		

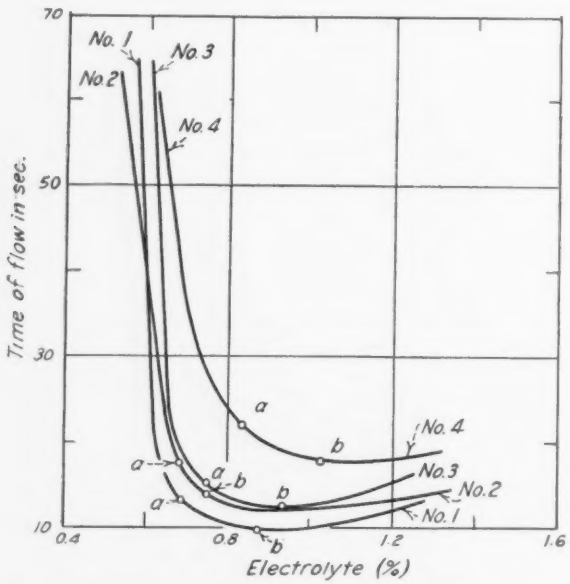

FIG. 3.—General ware body No. 5: curve No. 1, sodium silicate, sp. gr. 1.728; curve No. 2, sodium silicate, 0.25% soda ash, sp. gr. 1.728; curve No. 3, sodium silicate, sp. gr. 1.758; curve No. 4, sodium silicate, 0.25% soda ash, sp. gr. 1.758.

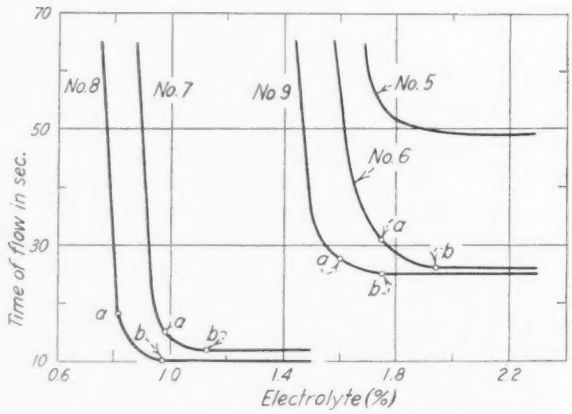

FIG. 4.—General ware body No. 5: curve No. 5, clay deflocculant No. 5, sp. gr. 1.760; curve No. 6, 1.5% clay deflocculant No. 5 plus sodium silicate, sp. gr. 1.755; curve No. 7, 0.625% clay deflocculant No. 5 plus sodium silicate, sp. gr. 1.732; curve No. 8, 0.500% clay deflocculant No. 5 plus sodium silicate, sp. gr. 1.732; curve No. 9, clay deflocculant No. 5, sp. gr. 1.727.

a pH of 6.25; when additional amounts of this deflocculating agent are added to the slip, there is no change in the rate of flow, but the pH is increased to 8.07. Evidently this lack of fluidity is not due to an insufficient number of OH ions but perhaps to the degree of repellency.

If the body contains certain types of ball clays, clay deflocculant No. 2 will not produce a slip thin enough for casting purposes. With a few ball clays and under certain factory conditions, this dispersing agent will cause a decided thickening action which may be broken up only by rapid stirring. It is evident, therefore, that this organic dispersing agent will have to be changed or used with other dispersing agents if it is to be useful in dispersing all types of clays.

(*A*) *Effect of Additions of Other Electrolytes:* The results of this series of tests are shown in Fig. 2. It is evident that small amounts of soda ash or sodium silicate in combination with clay deflocculant No. 2 would aid greatly to produce fluid slips of bodies which do not flow freely when dispersed with it alone.

(*B*) *Clay Deflocculant No. 5:* This dispersing agent was developed to produce more fluid slips of all types of ball clays. Its action on body No. 3 is shown in Fig. 1.

Clay deflocculant No. 5 produces much greater fluidity than No. 2, but the slip is not as fluid as with sodium silicate. This, however, is an advantage inasmuch as the fluidity produced is satisfactory for all casting purposes, and there is far less tendency for the nonplastics to settle out. It also permits the addition of excessive amounts of dispersing agent beyond that necessary to produce minimum viscosity, with the resulting automatic control of small variations in the properties of the ball clays.

(*C*) *Effect of Temperature:* Hot water makes a better casting slip than cold.[6]

Although temperature affects the viscosity of all slips, it seems to have a greater effect on slips containing clay deflocculant No. 2, especially the slips that are not completely dispersed by this organic dispersing agent. For example, a slip made from body No. 2 and containing 1.0% clay deflocculant No. 2 was tested at nine different temperatures. The specific gravity of the slip was 1.75, pH was 7.5, and 30.7% water was used as shown in the following data.

Temp. (°C.)	Flow (sec.)	Temp. (°C.)	Flow (sec.)
11	37	31	19
16	29	35	17
18	27	41	15
20	25	50	13
24	23		

Another test was made with body No. 3 in which the amounts of clay deflocculant No. 2 were varied and all samples were heated to 52°C. The results are given in the dotted curve in Fig. 1. When the temperature of the slip was raised from 27° to 52°C., the time of flow was decreased from 56 to 14 seconds; when the slip was completely dispersed (a flow of 14 seconds) by elevated temperatures and contained a slight excess of clay deflocculant No. 2, the viscosity remained almost constant on cooling to room temperatures. A temperature of 50°C., however, is far too high for factory practice, and some other answer must be found in the failure of clay deflocculant No. 2 to produce a fluid slip with certain types of ball clays.

(2) Body No. 5

This body was chosen for more complete tests because preliminary tests indicated that a fluid slip cannot be produced with clay deflocculant unless the specific gravity is below 1.72. Slips produced in this way, furthermore, had a tendency to thicken on standing.

(*A*) *Viscosity:* The viscosities produced by varying the amount of electrolytes were determined for two different densities. Sodium silicate and soda ash were used as electrolytes in the first series and clay deflocculant in the second. The results are plotted in Figs. 3 and 4.

Nothing unusual is noted from a study of the curves in Fig. 3, except perhaps the comparatively high amount of electrolyte necessary to produce minimum viscosity which is probably due to the large percentage of soluble salts in the ball clays.

The curves of Fig. 4 show that when clay deflocculant No. 5 is used alone as the dispersing agent, a very viscous slip is produced. It requires 2%, furthermore, to produce a minimum flow of 49 seconds when the specific gravity of the slip is 1.76 (curve No. 5, Fig. 4).

These slips thickened so fast that satisfactory viscosity results were difficult to obtain. Inasmuch as previous work indicated that this thickening effect could be partly overcome by using sodium silicate with clay deflocculant, varying amounts of sodium silicate were added to a slip containing 1.5% of clay deflocculant No. 5. This combination produces more fluid slips, but the minimum viscosity point is still rather high (curve No. 6, Fig. 4).

By decreasing clay deflocculant No. 5 to 0.625% and by reducing the specific gravity to 1.732 (curve 7, Fig. 4), more fluid slips were obtained with only a slight increase in the amount of sodium silicate over that used when 1.5% clay deflocculant was used. A further decrease to 0.5% of clay deflocculant and an increase of 0.025% sodium silicate produced slips as fluid as those obtained with sodium silicate alone (curve No. 1, Fig. 4).

These data seem to indicate that with this type of body about 0.5% of clay deflocculant No. 5 should be used with sufficient sodium silicate to produce the desired viscosity.

Continuing the study of slips with a comparatively low specific gravity, a series of samples was made up with clay deflocculant No. 5 as the only dispersing agent. The results are plotted on curve 9, Fig. 4. A comparison of this curve with No. 5 shows that by decreasing the specific gravity from 1.760 to 1.727 the fluidity is increased from a minimum flow of 49 to 25 seconds. This indicates that slips dispersed with clay deflocculant should have a low specific gravity, providing the casting time is not increased.

(*B*) *Thickening:* Two slips from each set of tests, one just before the minimum viscosity point was reached ((*a*) in Figs. 3 and 4) and the other at minimum viscosity (*b*), were tested in the Stormer viscosimeter for the rate of thickening on standing.

The results are recorded in Table IV, which shows that there is a marked decrease in the rate of thickening of a given slip as the minimum viscosity point is approached. When clay deflocculant is used alone as

TABLE IV

STORMER VISCOSIMETER TESTS ON BODY NO. 5

Slip No.	Specific gravity	Flow (sec.)	Number of revolutions on Stormer viscosimeter (time of standing in minutes) 0	2	5	10	15
1a	1.728	13	110	96	85	74	68
1b	1.728	11	188	187	186	184	184
2a	1.728	17.5	40	20	8	2	0
2b	1.728	14.0	58	40	28	20	18
3a	1.758	15.0	68	62	56	48	43
3b	1.758	12.5	124	123	122	121	120
4a	1.758	22.0	40	32	24	16	12
4b	1.758	18.0	50	47	44	42	40
6a	1.755	31.0	20	14	8	4	3
6b	1.755	26.0	32	30	27	25	24
7a	1.735	15.0	72	62	52	40	31
7b	1.735	12.0	140	136	132	128	126
8a	1.732	18.0	16	9	3	1	0
8b	1.732	10.0	165	161	156	152	149
9a	1.727	27.5	Too thick for testing				
9b	1.727	25.0	12	5	1	0	0

[6] Reference is made by the writers to the following books:
(*a*) E. C. Bingham, Fluidity and Plasticity, pp. 127 and 287. McGraw-Hill Book Co., New York, N. Y., 1922.
(*b*) A. B. Searle, Chemistry and Physics of Clays and Other Ceramic Materials, p. 247. Ernest Benn, Ltd., London, England, 1924.
(*c*) R. Houwink, Elasticity, Plasticity, and Structure of Matter, p. 251. Cambridge University Press, London, England, 1937.

the dispersing agent, the slips at the minimum viscosity point also show a tendency to thicken. All slips from curve No. 5 were too thick for testing. The use of sodium silicate with clay deflocculant has a marked tendency to overcome this thickening, but some of the advantages of an organic dispersing agent are counteracted.

(*C*) *Effect of Temperature:* Because a high temperature showed a marked tendency to increase the fluidity of slips dispersed with clay deflocculant, a more complete study was pursued with body No. 5.

NOTE: The Waring mixer was found to be suitable to heat slips to 60°C. and to agitate them at the same time without losing appreciable amounts of water from the slip. This mixer is efficient and may be used to mix small slip batches for all purposes. The mixing is rapid and so thorough that no part of a body remains unmixed and stuck to the stirrer or sides of the container.

If dry materials are used, they should be ground to about 10-mesh or finer to obtain the best and quickest results. This mixer, however, will blunge up lumps of ball clay in a few minutes. When the body materials are ground to 10-mesh or finer, a good mix may be obtained in about 10 minutes; the same result is gained if the body is in the plastic form.

The speed of the mixing device is so great that considerable heat is generated, especially if hot water has been used. A temperature of about 65°C. is obtained in about 15 minutes of mixing. An excessive amount of air is not introduced into the slip, however, as would be supposed from the high speed of the mixer.

Two slips, containing 1.5 and 1.87% clay deflocculant No. 5, respectively, were made up in the Waring mixer. Hot water was used, and a temperature of 60°C. was reached in 14 minutes of mixing; their specific gravity was 1.760, and they contained 30.0% water. When tested immediately at 60°C., the time of flow of both slips was 15 seconds. On cooling to a temperature of 28°C., the flow was 21 seconds, and there was no change in this flow after standing 48 hours.

A comparison of these results with those of curve No. 5, Fig. 4 (made in the usual way at room temperatures), shows that, under the latter conditions, a slip containing 1.5% clay deflocculant No. 5 is off the curve and that such a slip would be a very thick paste. The slip containing 1.875% clay deflocculant No. 5 had a flow of 50 seconds compared with 21 seconds when it was heated to 60°C. and cooled to room temperature.

The same body made into a slip with 1.125% clay deflocculant No. 5, with a specific gravity of 1.735, and with 31.4% water had a flow of 12 seconds at 60°C. and of 15 seconds when it was cooled to room temperatures. By comparing the data on this slip with the results obtained under ordinary conditions of mixing (curve No. 9, Fig. 4), the viscosity is shown to be well below the minimum viscosity point of curve No. 9, which required 1.75% clay deflocculant No. 5. In other words, heating a slip to 60°C. or higher not only decreases the viscosity to a marked degree, but it also decreases the amount of clay deflocculant necessary to produce minimum viscosity.

Body No. 5 slips, dispersed with sodium silicate, soda ash, or both and heated, thickened to a marked extent, becoming a thick pasty mass at 60°C.; on cooling to room temperatures, however, they returned to their original fluidity.

These tests seem to indicate, therefore, that high temperatures are advantageous only to slips dispersed with organic deflocculants, such as clay deflocculants No. 2 and No. 5.

(*D*) *Rate of Casting:* The casting rate at which a given slip will produce a piece of ware of desired thickness is important in valuating a dispersing agent. Because there are no standard tests for casting rate, several methods were tried with varying success, and the results are given in Table V.

(1) The slips were filtered and the filtrate was weighed, but there was such a small difference between slips of obviously different casting rates (column 4, Table V) that this method was given up at once.

(2) A test mold, 3 inches in diameter and 1 inch deep, was used; the excess slip was drained off; and the sample was removed from the mold (after standing 30 minutes or longer, if necessary), dried, and its thickness was measured. The average thickness of four test pieces for each slip, given in column (5), Table V, shows that although this method gave better results than the filtering method it did not show consistent or sufficient difference between slips of similar casting rates.

(3) The cast test piece was weighed as soon as it could be taken from the mold, dried, and the dry weight determined. These results show (columns (6) to (9), Table V) that either the wet or dry weight of a cast test piece is the best method to obtain the relative casting rate of different slips. Although the dry weight seems to give slightly more uniform results with a given slip than the wet weight, it is doubtful whether the small difference warrants the extra time necessary to obtain the dry weights.

The interesting point of these results is the marked decrease in casting rate of a slip containing sodium silicate as it approaches the minimum viscosity point (compare test No. 1 with No. 2). These results agree with factory experience.

The casting rate of slips dispersed with clay deflocculant No. 5, on the other hand, does not change to any marked degree when varying amounts are used. In other words, casting slips made up with clay deflocculant will have far more uniform casting properties under the average varying factory conditions.

(3) Body No. 6 (Pyrophyllite Type)

(*A*) *Viscosity:* Because preliminary tests showed that clay deflocculant No. 2 would not produce a slip with sufficient fluidity to give a reading on the viscosimeter unless it was heated to high temperatures, it was not included in this series of studies.

Figure 5 shows that it takes comparatively large quantities of sodium silicate and clay deflocculant No. 5 to disperse this body. To produce minimum viscosity, 1.4% sodium silicate and 1.9% clay deflocculant No. 5 are required because of the whiting in the body as well as the sulfates and carbonates in the talc and clays.

TABLE V

RATE OF CASTING BODY NO. 5

Column (1), slip No.; (2), clay deflocculant No. 5 (%); (3), sodium silicate (%); (4), filtrate weight (grams); (5), cast trial thickness (in.); (6), wet weight (grams); (7), wet weight (avg.); (8), dry weight (grams); (9), dry weight (avg.).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	0.50	0.3125	5.77	0.250	108.52		86.32	
					110.05	109.31	87.45	86.92
					109.37		87.01	
2	0.50	0.4688	5.31	0.144	66.32		54.29	
					67.84	67.07	55.40	54.87
					67.05		54.93	
3	1.50		5.89	0.220	99.51		77.43	
					98.77	99.54	77.91	77.98
					100.35		78.60	
4	1.60		5.75	0.189	90.74		71.28	
					90.11	90.30	71.20	71.28
					90.65		71.35	
5	1.75		5.82	0.190	90.32		69.32	
					89.79	89.68	70.12	69.40
					88.95		68.78	
6	2.00		5.65	0.189	85.79		67.52	
					87.15	86.43	68.61	68.02
					86.35		67.95	

Slip No. 1 = point *a*, curve No. 8, Fig. 4.
No. 2 = *b*, curve No. 8, Fig. 4 (minimum viscosity point).
No. 4 = *a*, curve No. 9, Fig. 4.
No. 5 = *b*, curve No. 9, Fig. 4 (minimum viscosity point).

A combination of clay deflocculant and sodium silicate produces the same maximum fluidity with the same amount of electrolyte as sodium silicate, with little thickening noted when the slips are allowed to stand for a short time.

Slips dispersed with clay deflocculant No. 5 (curve 2, Fig. 5), on the other hand, show a tendency to thicken, and the maximum fluidity obtainable under ordinary conditions of blunging and temperature is much less than that produced by sodium silicate or by a combination of clay deflocculant No. 5 and of sodium silicate. A combination of clay deflocculant and soda ash was also tried, but this combination produced a greater degree of thickening than clay deflocculant No. 2 and far more than clay deflocculant No. 5. Such slips would not flow and were very thick and "mushy."

(*B*) *Effect of Temperature:* Four slips from this series of tests were heated to 65°C. and at the same time were thoroughly agitated in a Waring mixer.

Column (1), sodium silicate (%); (2), clay deflocculant No. 5 (%); (3), flow before heating (sec.); (4), flow at 65°C. (sec.); (5), flow after cooling to 27°C. (sec.).

(1)	(2)	(3)	(4)	(5)
1.0600		25	45	19
0.4688	0.6250	30	35	20
	1.3500	65	15	16
	1.3750	37	14	16

The results shown in the tabular data indicate that slips dispersed with sodium silicate will thicken to a marked extent when they are heated to 65°C.; when they are cooled to 27°C., the viscosity is only slightly lower than it was before the slip was heated. On the other hand, the viscosity of slips deflocculated with clay deflocculant No. 5 is greatly decreased when heated to 65°C., and on cooling it is only slightly increased. Elevated temperatures undoubtedly will increase the dispersing power of clay deflocculant.

(*C*) *Rate of Casting:* Table VI shows that the rate of casting slips dispersed with sodium silicate is greatly decreased as the minimum viscosity point is approached (compare slips No. 1 and No. 2). The rate of casting,

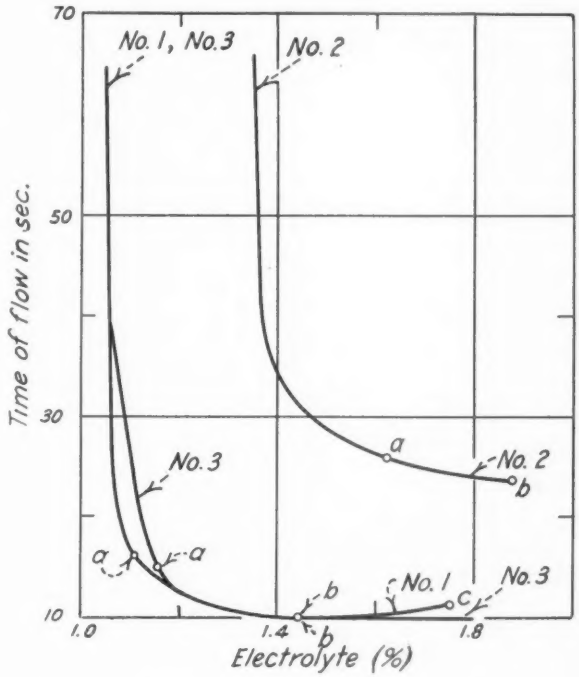

FIG. 5.—General ware body No. 6: curve No. 1, sodium silicate; curve No. 2, clay deflocculant No. 5; curve No. 3, 0.625% clay deflocculant No. 5 plus sodium silicate.

however, is not materially affected by varying amounts of clay deflocculant. Slip No. 6, containing 2.125%, casts almost as fast as slip No. 4 with 1.625% clay deflocculant No. 5.

TABLE VI

RATE OF CASTING BODY NO. 6*

Column (1), slip No.; (2), sodium silicate (%); (3), clay deflocculant No. 5 (%); (4), wet weight (grams); (5), wet weight (avg.); (6), dry weight (grams); (7), dry weight (avg.).

(1)	(2)	(3)	(4)	(5)	(6)	(7)
1	1.1250		108.38		85.20	
			106.25	106.72	83.34	83.85
			105.54		83.00	
2	1.4375		71.51		57.72	
			75.56	72.99	61.16	58.78
			70.90		57.46	
3	1.7500		68.07		55.15	
			67.02	67.27	54.51	54.64
			66.71		54.26	
4		1.625	94.95		74.32	
			96.40	95.64	75.43	74.58
			93.58		74.00	
5		1.875	92.53		72.66	
			93.56	92.54	73.11	72.86
			91.52		72.81	
6		2.125	90.20		70.51	
			92.58	90.92	72.65	71.25
			90.00		70.60	
7	0.5313	0.625	103.26		81.41	
			105.15	103.41	83.08	81.72
			101.81		80.68	
8	0.8125	0.625	69.19		56.12	
			67.33	68.59	54.68	55.98
			69.15		56.24	

* Minimum viscosity points are shown for slips Nos. 1, 2, and 3 on Fig. 14, curve 1, points *a*, *b*, and *c*, respectively; for slips Nos. 4, 5, and 6, on curve 2, points *a*, *b*, and *c*, respectively; for slips Nos. 7 and 8, on curve 3, points *a* and *b*, respectively.

From these results, it is obvious that the clays and other factors affecting casting slips may vary considerably without changing the casting behavior of a slip when clay deflocculant is used as the dispersing agent.

When sodium silicate is used with clay deflocculant No. 5, the ratio of clay deflocculant to sodium silicate should be greater than 1 to 1 if a material advantage is to be gained from the use of the deflocculant. In other words, at least two parts of clay deflocculant should be used with one part of sodium silicate to obtain a slip with a long casting range.

VI. Sanitary Ware Bodies

The compositions and physical properties of the slips are given in Table VII, and the viscosities are plotted in Figs. 6, 7, 8, and 9.

(1) Body No. 4

This body was chosen for more complete tests because it was readily dispersed by clay deflocculant (see Fig. 9).

(*A*) *Thickening:* The Stormer viscosimeter results in Table VIII show that there is little thickening of the slips unless the viscosity is comparatively high. Bodies may be developed, however, which will disperse readily with clay deflocculant and have little or no tendency to thicken on standing.

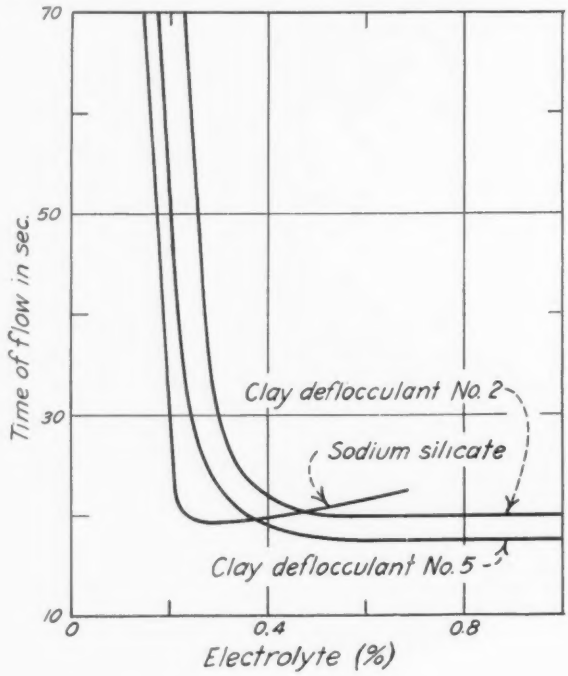

FIG. 6.—Sanitary ware body No. 1.

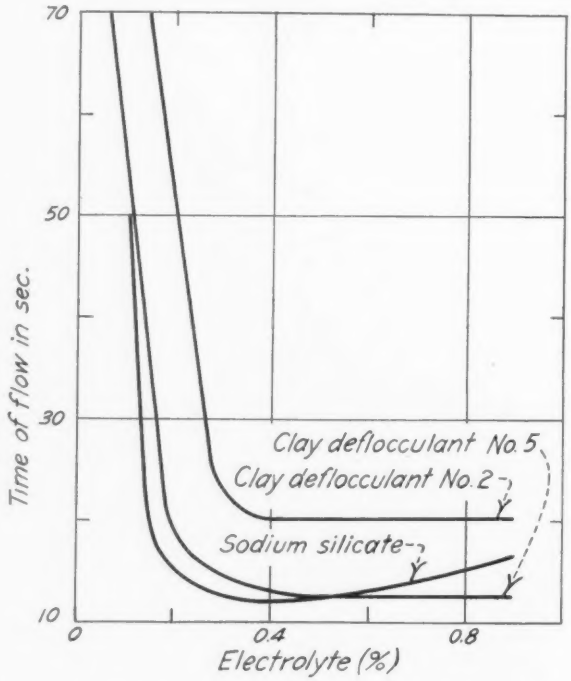

FIG. 7.—Sanitary ware body No. 2.

(*B*) *Effect of Temperature:* Six slips were heated to 65°C. and were thoroughly agitated in a Waring mixer; the results are given in the following data:

Column (1), sodium silicate (%); (2), clay deflocculant No. 2 (%); (3), clay deflocculant No. 5 (%); (4), flow before heating (sec.); (5), flow at 65°C. (sec.); (6), flow after cooling (sec.).

(1)	(2)	(3)	(4)	(5)	(6)
0.14375			22	60	22
	0.2750		39	20	17
	0.4375		19	11	12
		0.2250	17	17	17
		0.2500	14	14	14
		0.7750	12	11	11

TABLE VII

COMPOSITION AND PHYSICAL PROPERTIES OF SANITARY WARE SLIPS

Composition

	Body No. (%)			
	(1)	(2)	(3)	(4)
"Jasper" flint	26	26	26	27
N. C. feldspar	28	28	28	27
M. and M. English ball clay	12	9	9	10
Harris N. C. Lunday kaolin	7	7	7	
Moore and Munger English china clay	27	21	21	16
Ky.-Tenn. Clay Co. No. 5 ball clay		9		10
"Jernigan" ball clay			9	
"Peerless" S. C. kaolin				10

Physical Properties of Casting Slips

Body No.	Dispersing agent		Temp. (°C.)	Water (%)	Sp. gr.
	Sodium silicate		29	29.1	1.772
1	Clay deflocculant	No. 2	29	29.3	1.772
		No. 5	30	28.9	1.776
	Sodium silicate		30	29.5	1.765
2	Clay deflocculant	No. 2	28	29.1	1.782
		No. 5	30	29.2	1.774
	Sodium silicate		30	30.1	1.762
3	Clay deflocculant	No. 5	30	29.7	1.768
	Sodium silicate		27	27.1	1.822
4	Clay deflocculant	No. 2	28	27.1	1.822
		No. 5	27	27.0	1.828

TABLE VIII

STORMER VISCOSIMETER TESTS

Slip No.	Flow (sec.)	pH	No. of revolutions on Stormer viscosimeter, Standing time (minutes) 0	2	5	10	15
1*a*	22	6.40	60	48	40	32	25
1*b*	14	6.65	96	92	84	76	64
1*c*	11.5	6.85	172	168	166	164	160
2*a*	39	6.80	28	18	14	7	4
2*b*	16	7.40	84	76	72	66	60
2*c*	14	8.30	80	78	77	75	72
3*a*	17	6.75	68	60	52	50	48
3*b*	13	6.85	124	116	110	106	100
3*c*	12	7.05	120	115	109	108	104

(*C*) *Casting Rate:* The data on the casting rate of sanitary body No. 4 are recorded in Table IX, and the comparative results of sodium silicate and clay deflocculant are the same as in previous tests, i.e., there can be a much greater variation in the amount of clay deflocculant than sodium silicate before the rate of casting is materially changed.

VII. Vitreous Chinaware Bodies

Three typical vitreous chinaware bodies were used in this series of tests; their compositions and the physical properties of the slips are given in Table X; and their viscosities are given in Figs. 10, 11, and 12.

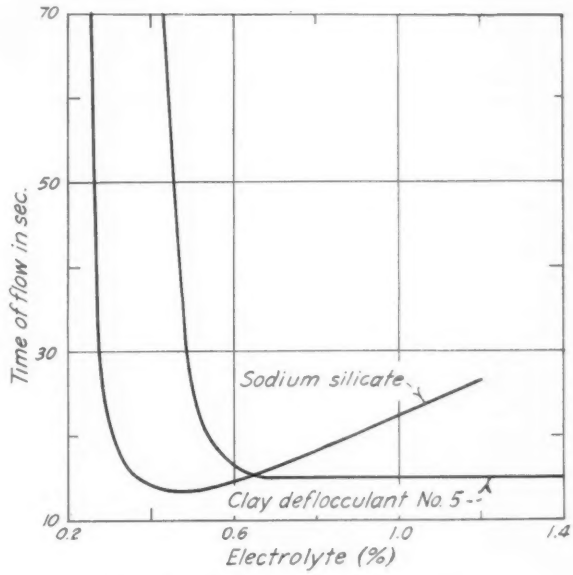

FIG. 8.—Sanitary ware body No. 3.

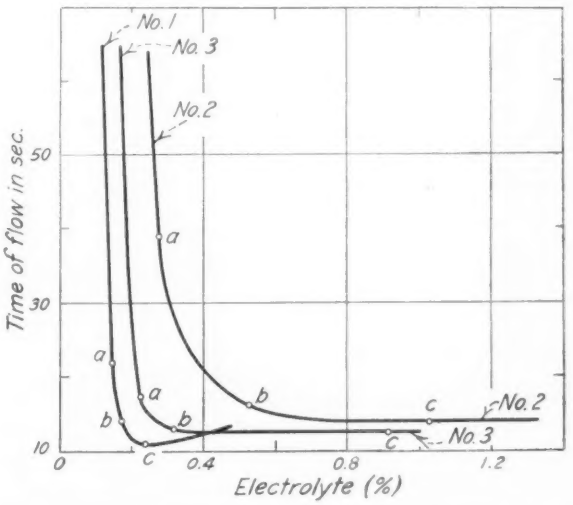

FIG. 9.—Sanitary ware body No. 4: curve No. 1, sodium silicate; curve No. 2, clay deflocculant No. 2; curve No. 3, clay deflocculant No. 5.

The results are similar to previous tests, except that as much sodium silicate as clay deflocculant No. 2 is required to produce minimum viscosity. All three dispersing agents, furthermore, give about the same fluidity, evidently due to the presence of calcium in the body. In other words, clay deflocculants No. 2 and No. 5 appear to be more efficient dispersing agents when the body contains whiting or marble.

Calcium in the body is known to have a marked tendency to increase the amount of dispersing agent necessary to produce a satisfactory casting slip[7] and this is equally true of clay deflocculants No. 2 and No. 5.

[7] A. B. Searle, *loc. cit.*, p. 242.

TABLE IX

SANITARY WARE BODY NO. 4 CASTING RATE*

Column (1), slip No.; (2), sodium silicate (%); (3), clay deflocculant No. 2 (%); (4), clay deflocculant No. 5 (%); (5), wet weight (grams); (6), wet weight (avg.); (7), dry weight (grams); (8), dry weight (avg.).

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1	0.14375			138.45		113.52	
				139.31	138.66	114.35	113.96
				138.24		114.00	
2	0.16875			125.37		103.85	
				126.16	124.11	104.16	102.91
				120.80		99.72	
3	0.23750			89.70		76.73	
				90.87	91.09	77.80	77.89
				92.72		79.14	
4		0.2750		163.83		132.44	
				156.88	160.35	126.45	129.07
				160.35		128.34	
5		0.5250		123.00		101.27	
				121.44	125.18	99.72	103.10
				131.10		108.32	
6		1.0250		112.65		91.81	
				110.00	111.04	89.13	90.03
				110.48		89.17	
7			0.22500	131.64		108.11	
				129.86	130.68	106.46	107.29
				130.55		107.32	
8			0.31250	115.48		96.24	
				117.08	116.24	97.78	97.01
				116.18		97.00	
9			0.91250	101.17		84.55	
				101.93	105.14	85.26	88.42
				103.24		96.57	

* Slips Nos. 1, 2, and 3 are represented on Fig. 9, curve 1, by points *a*, *b*, and *c*, respectively; slips Nos. 4, 5, and 6 on curve 2; slips Nos. 7, 8, and 9 on curve 3.

TABLE X

COMPOSITIONS AND PHYSICAL PROPERTIES OF VITREOUS CHINA SLIPS

Composition (%)

	(1)	(2)	(3)
"Jasper" flint	36	36	37
A-2 feldspar	18	18	18
M. and M. English china clay	17	17	30
Edgar Fla. kaolin	8	8	
Harris N. C. "Lunday" kaolin	10	10	4
M. and M. English ball clay	8		8
Imported whiting	2		2
Calif. magnesite	1		1
Ky.-Tenn. Clay Co. No. 4 ball clay		9	
H & G ground marble		2	

Physical Properties of Casting Slips

Body No.	Dispersing agent		Temp. (°C.)	Water (%)	Sp. gr.
	Sodium silicate		28	30.6	1.755
1	Clay deflocculant	No. 2	28	30.5	1.755
		No. 5	28	30.5	1.755
	(ground in ball mill)	No. 2	29	30.5	1.755
	Sodium silicate		28	30.0	1.763
2	Clay deflocculant	No. 2	29	30.0	1.764
		No. 5	28	30.1	1.762
	Sodium silicate		28	30.1	1.765
3	Clay deflocculant	No. 2	28	30.1	1.763
		No. 5	28	30.2	1.765

The effect of ball-mill grinding of the body is shown in Fig. 10. The ground body has greater fluidity with no increase in the amount of clay deflocculant No. 2.

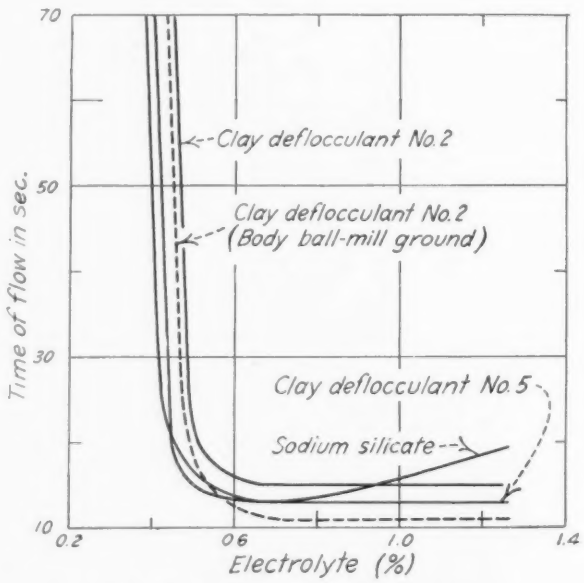

FIG. 10.—Vitreous china body No. 1.

VIII. Effect of Clay Deflocculant on Plaster

An organic dispersing agent obviously will not deteriorate a plaster mold as fast as sodium silicate or soda ash. Although this has proved to be the case in some factories, in others clay deflocculant does not increase the life of the molds.

To obtain more data on the subject, plaster bars, 6 by 1 by 1 inch, were made from a mixture of 57.9% standard pottery plaster and 42.1% water. The bars were allowed to dry slowly at room temperatures for about four weeks and then above a radiator for an additional 48 hours. After drying, 12 bars were soaked for one hour in 5% solutions of each of the following dispersing agents, viz., clay deflocculant No. 2, sodium silicate, and soda ash, and were dried for three days; another set was soaked and dried alternately three times, and a third set, five times. The dried bars were broken and the results are given in Table XI.

TABLE XI

Solution	Modulus of rupture (lb./sq. in.) No. of soakings			Water absorbed after five treatments (%) Soaking in water (min.)			
	1	3	5	3	8	13	23
Untreated	835	840	835	30.9	33.8	34.0	34.0
Sodium silicate	800	680	593	20.4	29.8	30.9	31.4
Soda ash	770	675	600	28.2	30.2	30.2	30.2
Clay deflocculant No. 2	855	849	750	30.4	32.4	33.4	33.4

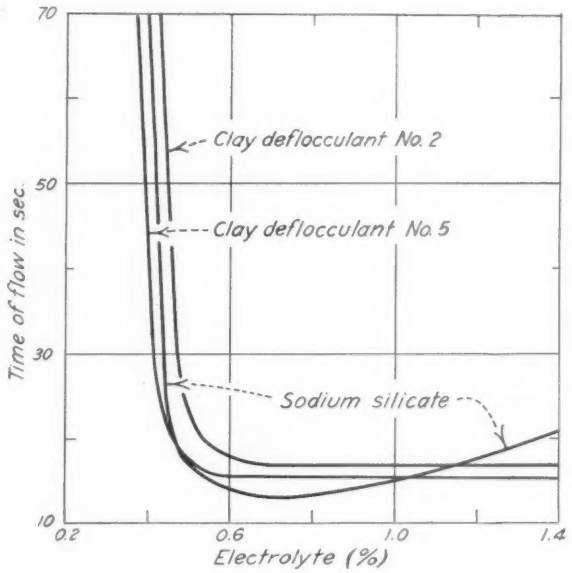

FIG. 11.—Vitreous china body No. 2.

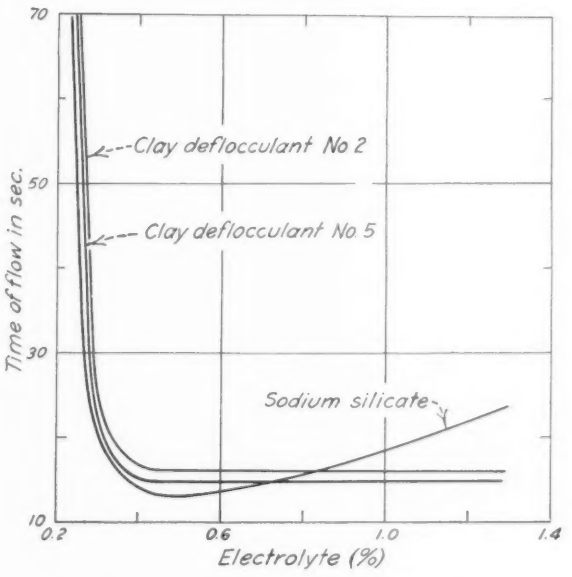

FIG. 12.—Vitreous china body No. 3.

These data show that both sodium silicate and soda ash decrease the strength of the plaster, whereas clay deflocculant increases it slightly and, therefore, should increase the life of molds.

To determine the effect different dispersing agents might have on the absorptive powers of plaster, the broken bars from the five soakings were soaked in water for periods of 3, 8, 13, and 23 minutes and were weighed after each soaking. The amount of water absorbed in percentage of the dry weight is given in Table XI. Sodium silicate and soda ash slow up the rate of absorption to a greater extent than clay deflocculant.

During this series of tests, soda ash showed a marked tendency to attack the plaster and to produce pinholes. After five soakings, the soda-ash bars lost 17% of their original weight and the sodium-silicate and clay-deflocculant bars gained about 1.5%.

IX. Summary

After four years of study on the use of organic dispersing agents in casting slips, the writers are convinced that present methods of control over many of the important properties of such slips are far from being a science. It seems fitting, therefore, that a number of investigations should be conducted on this subject. In addition to the data given in this report, considerable information has been obtained from the use of clay deflocculant in the factory, and the following facts appear to be fairly well established.

(1) The Stormer viscosimeter may be used to advantage in the laboratory to determine the tendency of slips to thicken or to become "mushy."

(2) Clay deflocculant No. 5 has less tendency to produce thickening or a thixotropic condition than No. 2.

(3) Sufficient clay deflocculant should be used to produce minimum viscosity in a slip with the least tendency to thicken.

(4) Slips which have a marked tendency to thicken when dispersed with clay deflocculant may be greatly improved by either of two methods: (1) with 0.5 to 0.75% of clay deflocculant No. 5 and sufficient sodium silicate to produce the necessary viscosity (soda ash cannot be used in this way in most cases be-

cause it will increase the degree of thixotropy); or (2) the slip may be heated to 60°C., agitated thoroughly, and cooled to room temperature; a period of 15 minutes is ample to heat and agitate the slip to obtain the desired results; this method produces a slip which is more stable and uniform than may be obtained by any other known way.

(5) Heating a slip dispersed with clay deflocculant also decreases the amount of electrolyte necessary to produce minimum viscosity.

(6) Casting a small test piece and determining either its wet or dry weight after it has been allowed to cast for 30 minutes is a good measure of the casting rate of slips.

(7) The amount of clay deflocculant may be varied to a much greater extent in a given slip than sodium silicate without affecting the rate of casting. This is one of the chief advantages of clay deflocculant as it permits the use of an excess amount which automatically takes care of variations in the body materials.

(8) Hydrogen-ion data are of questionable value, and if such tests are made they should be determined with a glass electrode and not colorimetrically.

(9) Clay deflocculant forms a very plastic cast and therefore facilitates trimming of and sticking on handles or spouts.

(10) Clay deflocculant will increase the life of plaster molds, especially when the body requires more than 0.4% sodium silicate and soda ash to disperse it.

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New York, N. Y.

METALLURGICAL STUDY OF CAST-IRON GLASS MOLDS*

By W. H. Bruckner, L. R. Kovac, and A. B. Wilder†

Abstract

This is a progress report in which certain metallurgical factors which influence the service behavior of cast-iron glass molds were studied. Little metallurgical research has been published in this field, and one of the purposes of this report is to create greater interest in the subject.

The possibilities were investigated for the improvement of glass molds by a study of of the metallurgical factors which control the service behavior of molds.

Typical failures of mold irons were examined and the results are described. Heat-checking and growth tests were made on several types of iron for which the data are reported.

I. Examination of Molds That Failed in Service

Three types of failures, consisting of cracks on the working surface of the molds, were studied. Figure 1 shows heat-checks which are normal to the major axis of an olive bottle half-mold. Figure 2 depicts another type of failure in a milk-bottle half-mold in which the heat-checks appear at the edges of the working surface where a sharp corner exists. An enlarged view of a heat-check, indicated by the arrow in Fig. 2, is shown in Fig. 3. The third type of heat-check (Fig. 4) consists of a network structure in a tumbler half-mold. It will also be observed that cracks occur at the sharp corners in this mold.

The microstructure of the mold shown in Fig. 1 consisted of small graphite flakes in the form of dendrites segregated in rosette-shaped colonies at the chilled surface. With increasing distance from the chilled zone, the dendritic structure disappeared and the graphite flakes increased in size. No combined carbon could be detected in the microstructure. The microstructure of the mold shown in Fig. 2 was similar to that of Fig. 1. A small amount of combined carbon, however, was present and the graphite flakes were not as large. The Rockwell hardness and tensile strength of the two molds are shown in Table I.

Table I
Hardness and Tensile Strength of Glass Molds

Mold	Rockwell B hardness (distance from working surface) (1/16 in.)	(1/2 in.)	Tensile strength (lb./sq. in.)
Fig. 1	78	50	13,800
Fig. 2	82	62	16,900

II. Heat-Checking Tests

A method to determine the susceptibility of cast iron to heat-checking by means of an accelerated cracking test would be of value, provided it would duplicate the types of defects which have been described. A satisfactory test of this type would then predict the service behavior of the mold iron with respect to heat-checking.

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* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 19, 1939 (Glass Division). Received July 1, 1939.

† Dr. Wilder is Assistant Professor and Mr. Bruckner is Research Associate in Metallurgical Engineering, University of Illinois, Urbana, Ill.

Low- and high-strength types of cast iron were used in the heat-checking tests. The material was in the form of 1.2- and 2-inch round test bars. The chemical analysis, tensile strength, and hardness are shown in Tables II and III. The microstructure of the low-strength test bars showed the presence of small amounts of free ferrite and steadite. The remainder of the iron consisted of graphite flakes and combined carbon.

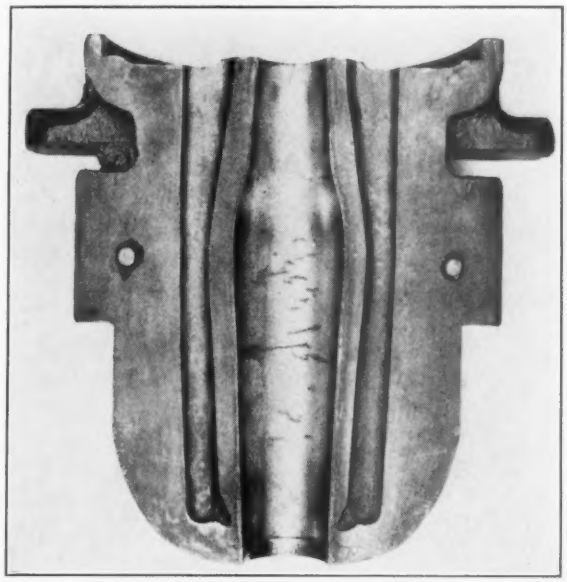

FIG. 1.—Olive bottle mold; 0.5 ×.

FIG. 2.—Milk-bottle mold; 0.5 ×.

TABLE II

CHEMICAL ANALYSIS OF CAST-IRON TEST BARS

Type	Total C	Si	Mn	P	S
Low-strength	3.56	2.25	0.59	0.45	
High-strength*	3.11	1.75	0.51	0.225	0.10

* For 2-inch bars of high-strength iron, ladle additions were made to give 1.25% Ni and 0.60% Cr.

TABLE III

HARDNESS AND TENSILE STRENGTH OF CAST-IRON TEST BARS

Type	Avg. Rockwell B hardness (1.2-in. diam.)	(2-in. diam.)	Tensile strength (lb./sq. in.)
Low-strength	85	75	20,500
High-strength	102	98	54,800

FIG. 3.—Heat-check in milk-bottle mold of Fig. 2; 3 ×.

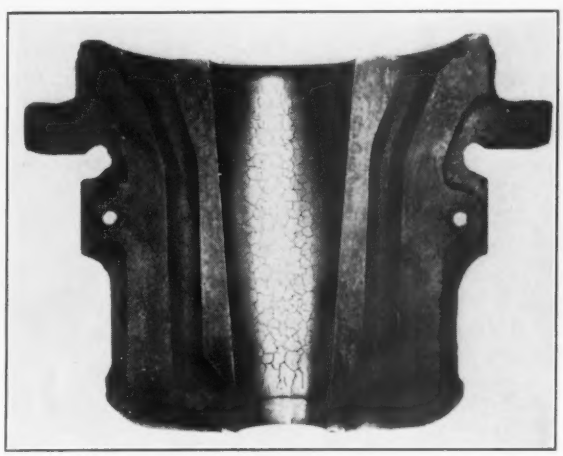

FIG. 4.—Tumbler mold; 0.5 ×.

The high-strength iron consisted of small amounts of steadite, no free ferrite, combined carbon, and smaller graphite flakes.

The polished solid cylinders used in the heat-checking tests were 2 by 2 inches and were machined from the 2-inch test bars; cylinders, 1 by 1 inch, were machined from the 1.2-inch test bars. The surface area per unit volume of the 1-inch cylinders was twice that of the 2-inch cylinders. The primary purpose of selecting the small cylinders was to show the effect of reduced mass in the cracking tests.

The test method used to produce heat-checks consisted of placing the cylinders on a refractory dish in an electric furnace at 1100°F.[1] The 2-inch cylinders were held at this temperature for one hour and the 1-inch cylinders for one-half hour. The specimens were quenched in water, and the scale was removed at intervals of ten cycles by electrolytic, cathodic cleaning in a sulfuric acid solution.

After ten cycles of heating and quenching the 2-inch cylinders, the number of heat-checks observed in the high-strength iron was slightly more than in the low-strength iron. For 20, 30, and 40 cycles, however, the heat-checks in the low-strength 2-inch cylinders outnumbered those in the high-strength 2-inch cylinders. The heat-checks in the low-strength iron after 40 cycles (Fig. 5) formed a network structure on the curved surface. This structure was not evident in the high-strength iron (Fig. 6) after 40 cycles. The cracks were more severe, however, for the high-strength iron. The heat-checks that formed on the flat surfaces of the cylinders were radial and extended inward from the sharp edges. These cracks were also associated with the notches in the specimens.

The 1-inch cylinders of low- and high-strength cast iron did not show visible heat-checks at the end of 10 cycles; only a few cracks were visible at the edges of the specimens after 20 cycles. The heat-checks after 30 cycles were comparable to those in the 2-inch specimens at the end of 10 cycles. The types of heat-checks in the 1-inch cylinders were similar to those of the same type of iron in the 2-inch cylinders.

The small cylinders were more resistant than the large cylinders to the formation of heat-checks, apparently owing to the mass effect in intensifying cracking in the cylinders of large mass. This factor may be useful in the design of excessively massive molds.

No detectable change was observed in internal structure or hardness of the specimens during the tests.

III. Growth Tests

The growth of cast iron in relation to the service behavior of molds was studied. Growth may not only be associated with the changes in dimensions of a mold but it may also be related to the stresses which cause heat-checks.

FIG. 5.—Two-inch low-strength iron cylinder after 40 cycles of heat treatment.

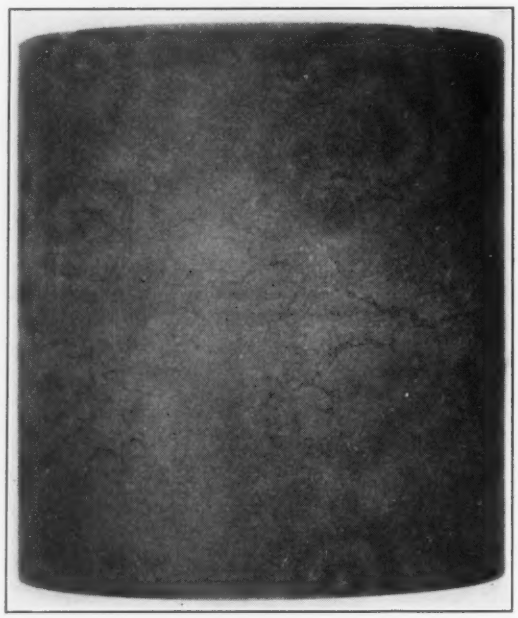

FIG. 6.—Two-inch high-strength iron cylinder after 40 cycles of heat treatment.

The growth test bars used were made from the 1.2-inch test bars of low- and high-strength cast iron. The method employed for these tests has been described by Dierker and Dawson.[2] The specimens consisted of 1-inch rounds, 2.5 inches long with four symmetrically arranged 2-inch gauge lengths consisting of Nichrome

[1] (*a*) "Materials for Glass Molds," *Glass Ind.*, **16** [6] 180–81 (1935); *Ceram. Abs.*, **14** [8] 186 (1935).
(*b*) B. Strauss, "Werkstoffe für die Glasformen," *Glastech. Ber.*, **3** [11] 407–12 (1926); *Ceram. Abs.*, **6** [3] 100 (1927).

[2] A. H. Dierker and H. H. Dawson, "Measuring Growth and Scale Resistance of Cast Iron," *Ohio State Univ. Eng. Expt. Sta. News*, **10** [4] 29 (1938).

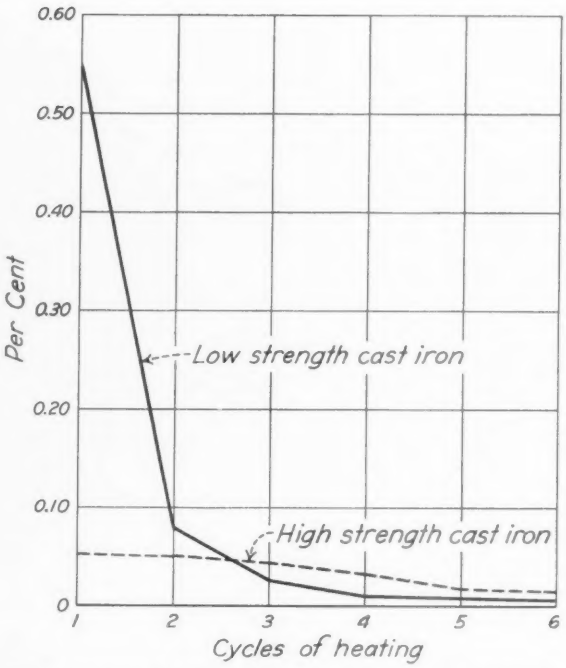

FIG. 7.—Rate of linear growth of low- and high-strength cast irons.

wire inserts. A Vickers hardness machine was used to make a square indent in the inserts. The diagonal of the indent was used for a reference line.

The growth test specimens were placed in an electric furnace at 600°F., and the bars were heated to 1100°F.[1] in two hours. They were held at 1100°F. for 22 hours and cooled at the rate of about 40°F. per hour. Four measurements were made on each growth test bar to correct for warping.

The results of the growth tests are shown in Fig. 7. The rate of growth in the low-strength iron during the first cycle was much greater than in the high-strength iron. For the additional five cycles, however, the rate of growth was quite similar for both types of iron. It is possible that the treatment of a low-strength iron mold before machining to eliminate the first cycle of growth may prove to be beneficial.

IV. Machinability Tests

The cost of machining glass molds is a factor of considerable economic importance. Several preliminary tests were made to determine the relative machinability of the low- and high-strength cast iron used in this investigation.

The horsepower input to a drill operating at a definite speed was measured. At a speed of 90 ft. per minute, the rating of the low-strength iron was 0.297 h.p. as compared to 0.437 h.p. for the high-strength iron. When the drilling speed was decreased to 60 feet per minute, the rating was 0.287 h.p. for the low-strength iron and 0.398 h.p. for the high-strength iron.

V. Conclusions

Some typical failures in cast-iron glass molds and a laboratory method for producing heat-checks have been described. The rate of growth of a low-strength pearlitic cast iron is shown to be greater than high-strength cast iron during the first cycle of testing. For the remaining five cycles, the rate of growth was about the same for both types of iron examined.

Acknowledgments

The results reported in this investigation at the University of Illinois were taken from an undergraduate thesis submitted by L. R. Kovac to the Department of Mining and Metallurgical Engineering of which A. C. Callen is the Head. C. W. Parmelee, Head of the Department of Ceramic Engineering, suggested the problem and was helpful throughout the investigation. The Gunite Foundries Corporation supplied all the specimens of low- and high-strength cast iron.

PRESENT APPLICATION AND POSSIBLE FUTURE DEVELOPMENT OF BLAST-FURNACE REFRACTORIES*

By W. R. McLain

Abstract

Changes in blast-furnace design and operation during the past three decades have been major factors in increasing blast-furnace campaigns from 500,000 to 2,000,000 tons. Studies of used-lining failures indicate that some order of increase in lining life and associated decrease in maintenance cost might follow the use of special refractories in the critical parts of blast-furnace linings. Increased size and operating temperatures of blast-furnace stoves have imposed more severe conditions on refractories, which fact emphasizes the importance of proper refractory selection.

I. Introduction

The earliest type of refractories used for blast-furnace linings in this country undoubtedly was mica schist or siliceous rock. This siliceous material was used until the latter part of the 19th century because fire brick at that time were not readily available and the cost was very high. Records show that siliceous rock was still used in the boshes of some furnaces in the early part of the 20th century. This material, as would be expected, caused considerable trouble because large pieces would spall off, and, before they could be dissolved by the slag, they would lodge in the iron notch, causing a delay in casting.

Practically all of the fireclay brick first used in blast-furnace linings were handmade. Many of these brick weighed nearly 50 pounds, and they were not particularly uniform either in refractoriness or in size.

During the period from 1900 to 1910, most of the brick linings above the mantle were between 45 and 60 inches thick, whereas below the mantle, i.e., the hearth and bosh, much thinner linings had followed the adoption of water cooling. Hearth diameters, during this time, ranged between 12 and 16 feet, and hearth depths of 18 feet were not infrequent.

Major changes in blast-furnace refractory construction after 1900 involved not only larger stacks with thinner linings but also larger hearths with decreased depth. Current construction is typified by stack linings approximately 36 inches thick, hearth diameters from 18 to 26 feet, and hearth thicknesses from 9 to 12 feet.

Three decades past, a furnace campaign of one-half million tons was unusual. Campaigns of one and one-half million tons are common today, and a campaign of two millions tons is sometimes made.

Improved refractories and methods of laying them no doubt have contributed to this increased tonnage. The extent of this contribution is difficult to evaluate, however, because accompanying better refractories are other improvements, such as (1) changes from hand filling to mechanical filling, (2) chemical and size grading of ores and, in some cases, sintering of ore, (3) improvement in the quality of the coke, (4) larger furnaces, (5) increase in the wind pressure, (6) decrease in the height of the bosh from 20 to about 8 feet, and (7) remarkably improved stock distribution arising from the use of revolving tops.

Increased output and decreased cost of iron have followed these changes, and improved refractories have made a considerable contribution to these gains. The extent of this contribution, however, cannot be appraised precisely by the tonnage yardstick because the duration of a furnace campaign is affected in no small measure by (1) the types of product made, (2) banking or blowing out due to the business cycles, and (3) furnace practices, all of which may shorten furnace life to some indeterminate degree. In the attempt to increase lining life, therefore, small changes in design and operation of the furnace may have far more effect on lining life than like improvements in the quality of refractories.

The observed refractory performance in different parts of the blast furnaces will be discussed to illustrate the types of failure commonly encountered and also to suggest remedies for these failures.

II. Hearths

Increased hearth diameters and the associated larger tonnages have imposed extremely severe conditions on this section of the furnace. As a result, some furnaces have lost as much as 1500 tons of molten iron through the furnace hearth. When these losses occur, the furnace is usually shut down from 24 to 48 hours to stop the escape of additional molten iron and to solidify it in the lower section of the hearth. The furnace is then returned to operation and the campaign usually is finished with no further difficulty. In addition to the loss of time and metal and the associated cost and delay of salamander removal at relining, the escape of metal through the hearth adds to the accident hazard. These losses are more frequent with a larger hearth diameter because, with an increased hearth area, water cooling is less effective in retarding hearth erosion.

The erosion of hearth refractories has been studied by comparing the tonnage produced during a campaign with the size of the salamander found at the end. These studies cover thirty campaigns, and they indicate that the salamander is formed at or about the 300,000-ton level of iron production. This view is substantiated by the fact that losses of molten iron through the

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hearth usually occur before one-half million tons of the campaign is reached.

Figure 1 shows typical salamander burn-out lines after a furnace campaign of more than one and one-half million tons. The salamander has gone through the 9-foot brick hearth and into the concrete foundation. The size of salamanders ranges between 250 and 1100 tons, and their removal requires from two to six weeks. The four zones shown in Fig. 1 are described and discussed as follows:

Zone (1): This zone lies in contact with the salamander and is composed of coarsely crystalline corundum (Al_2O_3) and anorthite ($CaO \cdot Al_2O_3 \cdot 2SiO_2$). It is from 1 to 3 inches thick, light gray in color, and filled with stringers of iron and graphite. The formation of the anorthite and corundum may be ascribed to the reaction of the slag with the fire-clay brick, which results in a melt high in silica and low in alumina. This melt rises to the slag in the crucible and thereby produces a concentration of alumina and anorthite at the surface of the brick.

Zone (2): This zone occupies the next 1 to 2 feet of the brickwork immediately behind the corundum-anorthite layer. The main constituent is mullite with a small amount of glass. The three to five years of soaking heat combined with the pressure, ranging from 35 lb. per sq. in. at the top of the hearth to about 65 lb. per sq. in. at the bottom, have squeezed the clay grains together so that intergrain voids and the porosity of the brick are practically nil.

Reduction in volume of the brick is accompanied by an increase in bulk density from 130 lb. per cu. ft., the original density of the brick, to 170 lb. per cu. ft., as well as by a decrease in brick volume of 23.9%, which was the initial true porosity of the brick. A large number of the brick joints containing stringers of iron, from paper-thin up to 3 inches thick, are also found here. These joints and the adjacent vitrified brickwork are shown in Fig. 2.

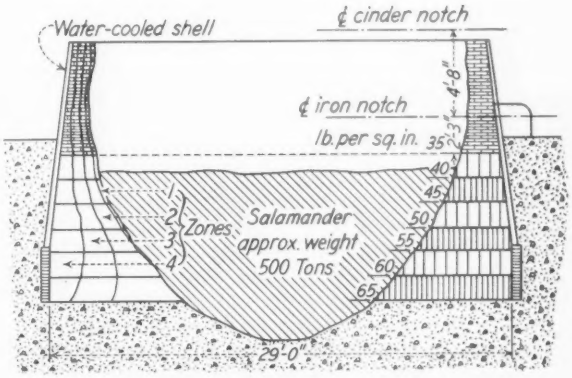

FIG. 1.—Section showing general outline of salamander.

FIG. 2.—Vitrified brick from zone 2 showing iron penetration.

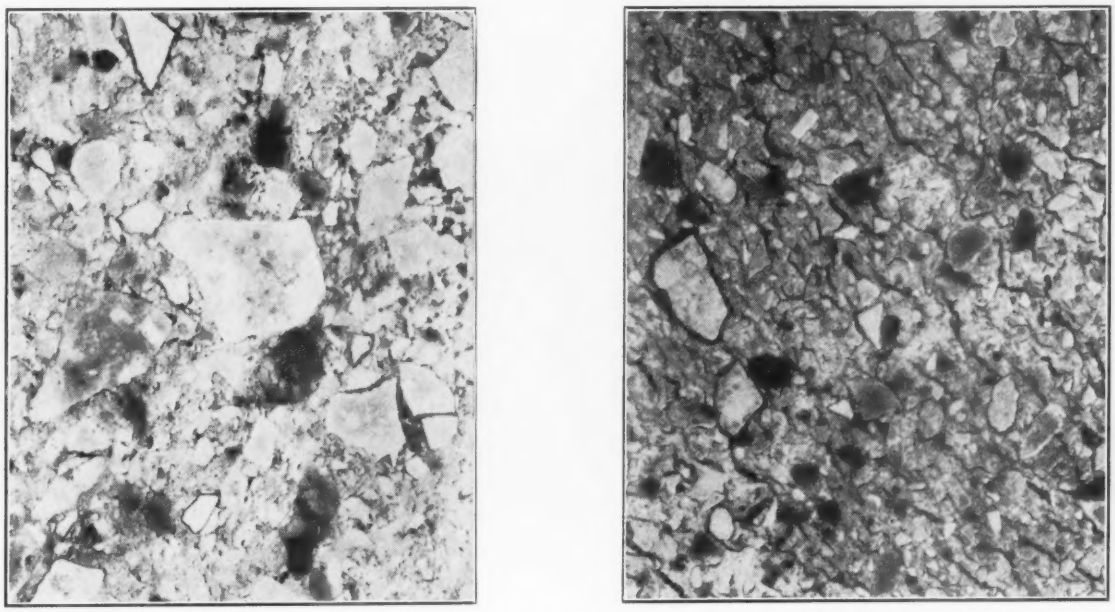

FIG. 3.—Polished sections of brands A (*left*) and B (*right*), 4 ×.

Zone (3): There is a large development of mullite with no noticeable change in brick volume or of grain structure.

Zone (4): Water cooling has prevented any noticeable change in the original structure or volume of the brick.

The properties of two brands of bottom blocks and the vitrified brick from zone 2 are shown in Table I.

TABLE I

BOTTOM BLOCK AS RECEIVED COMPARED WITH VITRIFIED ZONE

	Brand A	Brand B	Vitrified brick of zone (2)
Analysis			
SiO_2	53.6	54.1	57.0
Al_2O_3	40.0	40.1	36.5
TiO_2	2.0	2.4	2.2
FeO and Fe_2O_3	2.2	1.9	1.6
CaO	0.3	0.4	0.6
MgO	0.7	0.4	0.5
Alkalis	1.4	0.7	1.6
P.C.E.	32–33	32½–33	
Reheat, linear change cone 30 (% shrinkage)	0.7	0.2	
True porosity (%)	23.6	12.8	0.0
Density (lb./cu. ft.) bulk	130	147	170
Density (lb./cu. ft.) true	170	170	170

Of the two brands, brand B may be expected to shrink less in hearth service than brand A because of its relatively greater density and lower porosity. It follows that a hearth constructed with brand B would reduce ultimate joint size and thus minimize the occurrence of the iron-filled joints (see Fig. 2), provided both brands are equal in trueness of dimensions and straightness.

The difference in porosity of brands A and B (as manufactured) may be accounted for by the difference in the voids around the grains of clay (see Fig. 3) because the bond between the grains in brand B is closer and more uniform than in brand A.

Although greater density and uniformity of dimensions and straightness of hearth blocks should tend to reduce the costs and hazards of salamander formation, the best type of fire-clay brick for modern blast-furnace hearth construction probably will fall short of adequate insurance against molten iron losses through the hearth and costly occurrence of salamanders unless more efficient cooling is adopted and hearth blocks are designed to prevent floating.

(1) Carbon Hearths

Hearths and boshes of machined carbon blocks and of rammed carbon are in everyday use in German blast furnaces. Limitations in the quality of German fire clays and the low machining cost of carbon blocks apparently have made their use satisfactory. Although German blast-furnace operators chiefly use machined carbon block, keyed in place, to retard floating and to prevent the formation of salamanders and losses of molten metal through the hearth, rammed carbon hearths have also been used, some of which have given satisfactory results.

The use of the accurately machined multishaped carbon-hearth blocks, which typify German practice, does not appear to be commercially warranted in blast-furnace practice in the United States, and no satisfactory substitute for these blocks is available at this time. The value of using carbon brick, 18 by 9 by 4½ inches, for hearth construction is also questionable.

Table II shows the relative costs of the various types of brick available for hearth construction; the carbon costs, however, are not for accurately machined or multishaped blocks.

TABLE II

RELATIVE COST OF REFRACTORIES FOR HEARTH CONSTRUCTION

Material	Size (inches)	Relative approx. cost per 9-in. equivalent
Clay, stiff-mud ground	18 x 9 x 4½	1
Clay, air-rammed	18 x 9 x 4½	3.0
Clay, air-rammed	24 x 24 x 12	3.8
Carbon, extruded and baked	18 x 9 x 4½	2.9*
Carbon, extruded and baked	24 x 24 x 12	2.9*
Sillimanite, air-rammed	18 x 9 x 9	6.7
Mullite, electrically fused	18 x 9 x 4½	11.4

* Estimated unmachined.

III. Stack Lining

(1) Bosh

Because the brick in this section absorb 10 to 20% of alkalis, they cannot be expected to withstand the high temperatures attained in the bosh without being water-cooled.

(2) Inwall and Top

Not only is the service life of the furnace determined by the stability of the inwall and top, but marked localized wear adversely affects the coke rate, stock movement, gas distribution, and therefore the operating efficiency.

Figure 4 shows two typical zones of marked localized wear. The first zone extends downward about 5 to 10 feet from the lower edge of the stock-line wearing plates, and the brick lining frequently erodes so much that the plates fall out, hot spots occur, and stock distribution is unfavorably affected. Wear could probably be minimized in this top section by the use of brick of cone 20 or above, so fired that it would be 10 to 15% harder or more vitrified than the top brick commonly used. Such brick would have characteristics approaching those of paving brick. The transition from the present type of brick to the more vitrified pavers, however, should be made gradually because the effect of the cold charge on spalling in this section is not well known.

The second zone of localized wear extends upward about 10 to 15 feet above the mantle.

The major cause of lining deterioration in these two sections may be ascribed to brick disintegration and erosion, and if the furnace lines of these sections could be maintained the 25-foot section in between would seldom give trouble.

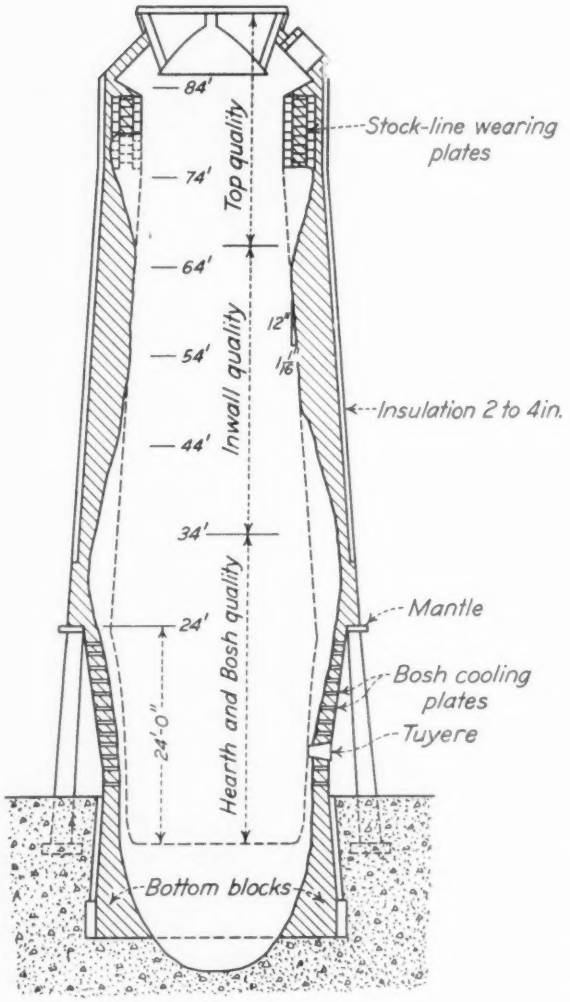

FIG. 4.—Burn-out lines of furnace.

The foregoing changes in stack lines have been largely ascribed to brick disintegration arising from carbon deposition around iron oxide concentrations in the brick. Nesbitt and Bell[1] found that this disintegration was most severe between temperatures of 780° to 880°F. and with brick containing coarse particles of Fe_2O_3. In their studies of used blast-furnace linings, they found globules of lead and zinc associated with the carbon deposits. They also reported 10 to 12% of alkalis three inches in from the inner surface and extending up from the bosh to 20 feet above the mantle. They stated, however, that disintegration of the brick was caused only by carbon deposition.

Furnas[2] states that disintegration may be prevented by converting all of Fe_2O_3 in the brick to Fe_3O_4 or FeO and Townsend[3] believes that the iron oxide content of the brick is the controlling factor in disintegration.

Other authorities have pointed out that, by combining the iron oxide in the brick with the alumina and silica by the agency of harder firing, disintegration could be prevented. For these reasons, refractories manufacturers probably increased firing temperatures and adopted a reducing fire in an effort to attain this end. Microscopic and chemical analyses of top-quality blast-furnace brick, however, show that in spite of such firing the iron oxide is not combined with silica and alumina but exists mainly as magnetite or as 81% Fe_3O_4 and 19% FeO.

Blast-furnace brick, which are fired as described, disintegrate, and although it is not maintained here that carbon does not contribute to this disintegration, the following evidence suggests that if the iron oxide were

[1] C. E. Nesbitt and M. L. Bell, "Solving Furnace Lining Problems," *Iron Trade Rev.*, **72**, 1603 (1923).

[2] C. C. Furnas, "Disintegration of Blast-Furnace Linings Due to Carbon Deposition," *Jour. Amer. Ceram. Soc.*, **19** [6] 177–86 (1936).

[3] H. E. Townsend, "Reduction of Blast-Furnace Lining Disintegration," *Iron Trade Rev.*, **74** [3] 232–34 (1924); *Ceram. Abs.*, **3** [6] 200 (1924).

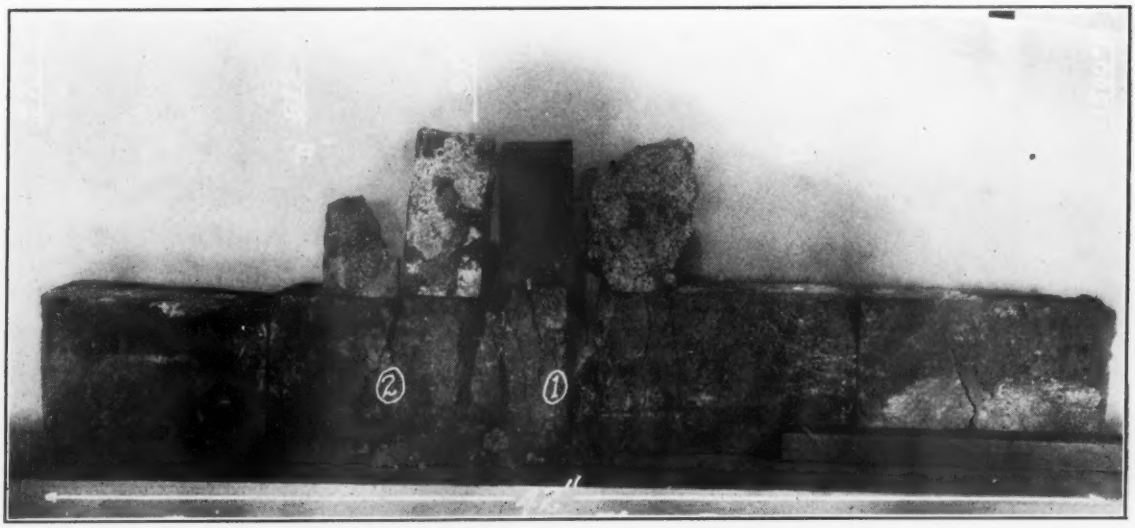

FIG. 5.—Brick section from No. 10 blast-furnace lining 40 ft. from top, showing disintegration.

converted to Fe_3O_4 and FeO or combined with the alumina and silica this phenomenon will still occur.

Figure 5 shows a section of brick from a point in the lining 40 feet from the top where there has been little erosion. The temperatures shown have been calculated from an estimated inner brick-surface temperature of 1500°F. The disintegrated section between A and B has been subjected to estimated temperatures ranging from 825° to 1250°F., and deposits of carbon, globules of lead, and large crystals of sphalerite (ZnS) were found in this section. The chemical analyses (Table III, columns (2) and (3)) indicate that there was no increase of alkalis in this section but an increase of 1 to 2% of iron oxide has taken place and some of this iron oxide has been reduced to metallic iron.

A severely disintegrated section of a lining, approximately 1 foot above the mantle, has also been studied petrographically and chemically.

This section lay behind an inner wall face of vitrified brick, which was about 6 inches thick. The disintegrated section, which was also about 6 inches thick, was so completely broken down that it could be easily crushed to a fine powder. This powder, analyzing 12.3% of alkalis, consisted entirely of nepheline crystals [$(Na,K)AlSiO_4(SiO_2)x$]. This crystallization took place in the solid state and disrupted the original brick structure. Alkalis likewise occur in regions 15 to 20 feet above the mantle, but the percentages and the corresponding amount of nepheline are less.

This discussion of disintegration indicates (1) that the inwall lining of a blast-furnace stack, about 20 feet up from the mantle, may be expected to disintegrate because of alkali pick-up and the formation of nepheline; (2) that the most severe disintegration corresponds to the greatest alkali increase; and (3) that neither the conversion of iron oxide to Fe_3O_4 and FeO nor the elimination of iron oxide from the clay will prevent carbon disintegration because 1 to 2% of iron is absorbed by the brick during its service life.

Under such conditions and in the section discussed, the use of carbon linings, water cooling of the brickwork, or the development of a stable brick initially containing 12 to 15% of alkalis might be expected to maintain furnace lines more efficiently and thereby to increase furnace life and efficiency.

IV. Blast-Furnace Stoves

The size of stoves has kept pace with the increase in furnace size so that the 66-foot stoves of the past two decades have been replaced by modern stoves of like diameters but nearly 100 feet high.

TABLE III

CHEMICAL ANALYSES OF ORIGINAL BRICK COMPARED WITH DISINTEGRATED BRICK

Column (1), brick as received; (2), point 1, 20 inches in from hot brick face and 40 ft. from top; (3), point 2, 26 inches in from hot brick face (see Fig. 5) and 40 ft. from top; (4), carbon spots; (5), 6 inches from inner surface at mantle.

	(1)	(2)	(3)	(4)	(5)
SiO_2	51.96	50.58	52.50		44.90
Al_2O_3	40.43	38.29	38.87		34.73
TiO_2	2.16	1.90	2.00		1.50
Fe		1.32	0.99	0.32	
FeO	0.77	1.63	1.47	10.08	4.06
Fe_2O_3	1.20	1.11	0.51	0.18	0.30
MnO		0.26	.21		.41
CaO	0.32	.28	.42	.43	.64
MgO	0.52	.02	.25		.45
ZnO		1.21	.19		
Sulfur		0.08	.05	.40	.06
Alkalis	1.50	.95	.92	.56	12.30
Carbon		.94	.28	88.10	0.39
Apparent porosity	15.5%				
P.C.E.	32–33				13–14
Bulk density (lb./cu. ft.)	143				

FIG. 6.—Blast-furnace stove checkers after 2 one million-ton campaigns.

Accompanying this increase in height have been other changes, such as the use of insulation next to the steel shell, cleaner gas, and an increase in heating surface per unit weight of refractory, all of which have contributed to the higher temperatures in modern stoves.

In stoves not equipped with appropriate pyrometers, unduly high temperatures frequently cause serious deformation of the upper twenty-five feet of the checker work as it is usually constructed. Deformation of this type is shown in Fig. 6 and was observed at the close of two 1,000,000-ton campaigns.

In this example, a settlement of about 2 feet has taken place, accompanied by a general shifting of the checkerwork away from the combustion chamber wall and the consequent crushing of the checkers on the opposite side of the stove. The uneven distribution and high velocity of the gases, higher temperatures, and the hot-load deformation of the brick used here have all contributed to the shifting shown in Fig. 6. This shifting has been attributed to the absorption of alkalis which, when it occurs, decreases the hot-load carrying capacity.

Chemical analyses of brick from the cited sections indicate that no alkali absorption had taken place and therefore that deformation and shifting in these upper sections probably arise from the use of brick with undesirable low hot-load characteristics.

Figure 7 shows another example of checkerwork and combustion wall distortion. The large pieces of refractory, which appear in the front and middle foreground of the top surface of the checkerwork, are spalled parts of the dome plug used to close a circular opening in the stove dome. Such spalls reduce the available checker openings by not less than 2%, and their occurrence may be ascribed to high temperature and the concurrent vitrification and shrinkage of the type of fire-clay brick customarily used.

Like conditions, i.e., vitrification, shrinkage, and spalling, occur in that section of the combustion chambers which extends about 25 feet up from the gas burner opening.

The use of superduty fire brick in not less than the top ten feet of checkerwork and combustion chamber wall as well as the dome plugs and in the area adjacent to the gas burner in the combustion chamber should add appreciably to stove life and efficiency in addition to reducing repair and maintenance costs.

V. Conclusions

This study of the service failures of blast-furnace refractories of the type generally used suggests that somewhat longer furnace campaigns and decreased operating delays and costs might be expected to follow the use of selected refractories in the critically attacked parts of stacks, stove linings, and other parts.

Blast-furnace refractory costs, including demolition and rebuilding labor, appear to constitute between 7.7

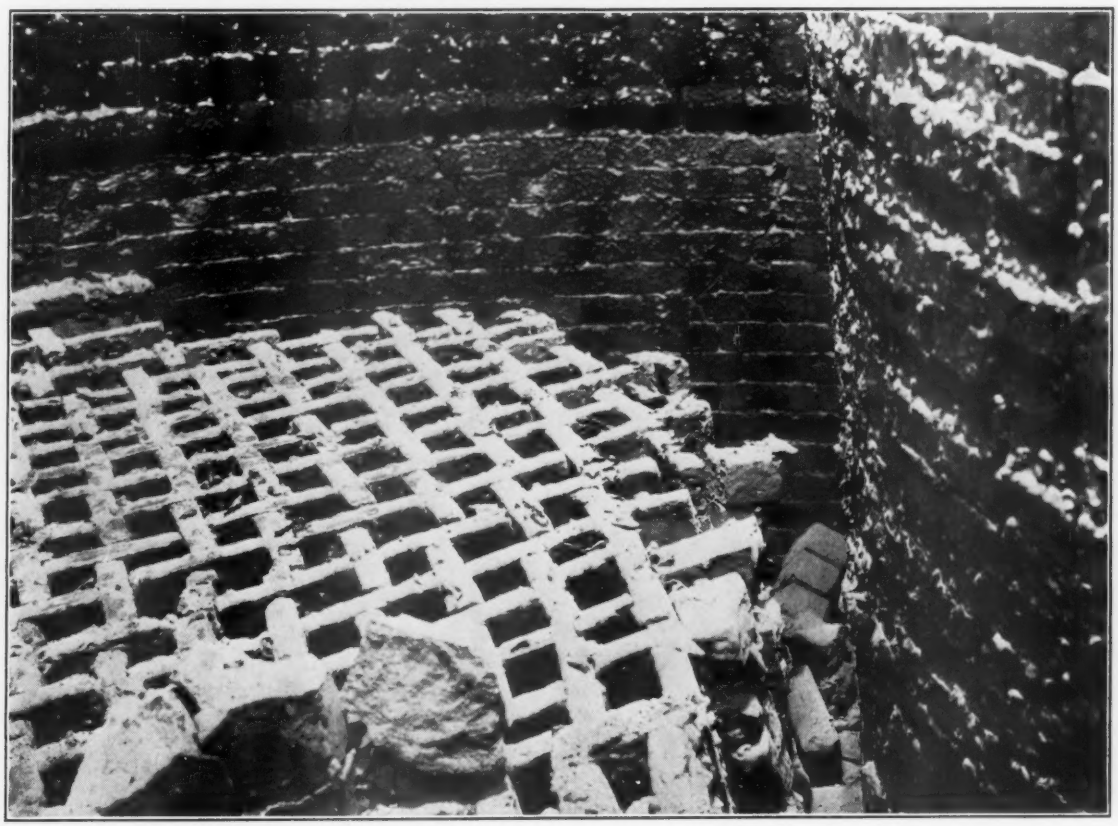

FIG. 7.—Blast-furnace stove checkers after 2 one million-ton campaigns.

and 9.4% of the "cost above" for producing pig iron, and the additional cost of selected refractories judiciously applied probably would be profitable because such applications would minimize (*a*) undue rate of salamander growth and the concurrent shutdowns and hazards of breakouts; (*b*) undue changes in furnace lines and the concurrent loss of furnace efficiency; (*c*) decreased stove efficiency; and (*d*) costs of delayed production, as well as undesirable repair and maintenance expense.

The gain or loss arising from the use of improved refractories nevertheless can be made clear only through the agency of carefully planned and patiently executed field experiments.

Acknowledgment

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FRACTIONATION OF NONPLASTIC POWDERS BY SEDIMENTATION IN WATER*

By Stanley E. Lull and A. S. Watts

Abstract

A study was made on the application of the principle of quiet sedimentation in water to which a deflocculant was added to determine the proportions of particles within various size ranges. The apparatus used is a cylindrical sedimentation vessel, equipped with an inverted truncated cone to introduce the material to be classified, and a large-sized syphon connected with four arms equally distributed across the lower section of the sedimentation vessel. The results obtained show that a successful classification of the materials studied is possible and reproducible. The classification time and the necessity for resedimentation depend on the degree of accuracy and the limits to which the classifications of smaller particles are sought.

I. Introduction

Although the standard screen analysis test may be used on 43-micron diameter particles (325-mesh) with a fair degree of accuracy if the screens are new and in good condition, the particle shape greatly affects any screen analysis. Nonplastics as well as plastics, furthermore, are supplied to the various ceramic industries so finely divided that only a small portion remains on a 325-mesh sieve. Some equipment other than the screen is therefore necessary, not only to determine particle-size distribution but to separate the finer from the coarser fractions in sufficient quantity to study the effect of the size fractions in specimens for commercial use.

The object of this investigation was to develop a wet method of fractionating nonplastic ceramic materials by decantation in sufficient quantity to use in test specimens as well as to measure the particle-size distribution of these materials.

II. Theory

Stokes' law states that when a small body is allowed to fall freely in a fluid medium the extent of the fluid medium, being infinitely great compared to the small body, soon reaches a constant velocity. The downward acceleration of the small body is exactly balanced at this point by the friction of the particle on the fluid medium. This law may be stated as follows:

$$V = \frac{2(D - d)}{9y} g r^2.$$

Where V = velocity of fall (cm./sec.).
D = density of particles (gm./cc.).
d = density of medium.
y = coefficient of viscosity of medium (dyne-sec./cm.^{2} or poises).
g = acceleration constant (cm./sec.^{2}).
r = radius of particles (cm.).

(1) Literature Review

The literature on particle-size distribution measurement is voluminous, and only a few of the outstanding references are given at this time.

(1) R. F. Geller, D. N. Evans, and A. S. Creamer, "Effects of Particle Size of Flint and Feldspar in Whiteware," *Bur. Stand. Jour. Research*, **11** [3] 327–40 (1933); R.P. 594; *Ceram. Abs.*, **12** [12] 427 (1933).

(2) H. G. Schurecht, "Elutriation Tests on American Kaolins," *Jour. Amer. Ceram. Soc.*, **3** [5] 355–78 (1920).

(3) P. S. Roller, "Size Distribution of Ceramic Powders Determined by Particle-Size Air Analyzer," *ibid.*, **20** [5] 167–74 (1937).

(4) H. G. Schurecht, "Sedimentation as Means of Classifying Extremely Fine Clay Particles," *ibid.*, **4** [10] 812–21 (1921).

(5) C. J. Van Nieuwenburg and W. Schoutens, "New Apparatus for Rapid Sedimentation Analysis," *ibid.*, **11** [9] 696–705 (1928).

* Presented at the Forty-First Annual Meeting, American Ceramic Society, Chicago, Ill., April 18, 1939 (Materials and Equipment Division). Received April 18, 1939.

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(6) S. B. Biddle, Jr., and Alexander Klein, "Hydrometer Method for Determining Fineness of Portland-Puzzolan Cements," *Proc. Amer. Soc. Testing Materials*, **36** [Part II] 310–31 (1936); *Ceram. Abs.*, **16** [6] 181 (1937).
(7) W. J. Kelly, "Determination of Distribution of Particle Size," *Ind. Eng. Chem.*, **16** [9] 928–30 (1924).
(8) C. G. Duncombe and J. R. Withrow, "Kelly Tube and Sedimentation of Portland Cement," *Jour. Phys. Chem.*, **36** [1] 31–51 (1932); *Ceram. Abs.*, **11** [5] 332 (1932).
(9) Edward Schramm and E. W. Scripture, Jr., "Particle Analysis of Clays by Sedimentation," *Jour. Amer. Ceram. Soc.*, **8** [4] 243–52 (1925).
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(11) R. H. Bray, "Significance of Particle Size Within the Clay Fraction," *ibid.*, **20** [8] 257–61 (1937).
(12) F. H. Norton and S. Speil, "Measurement of Particle Sizes in Clays," *ibid.*, **21** [3] 89–97 (1938).
(13) W. L. Fabianic, "Microscopic Control of Particle Size in Refractory Manufacture," *ibid.*, **18** [1] 23–25 (1935).
(14) L. A. Wagner, "Method for Determination of Specific Surface of Portland Cement," *Proc. Amer. Soc. Testing Materials*, **33** [Part II] 553–70 (1933).

III. Method and Apparatus

The decantation method was used in which the material that has settled from the surface of a liquid medium to a depth just below the level of decantation is removed by means of an inverted syphon tube, dried, and weighed.

The apparatus used was a round, copper sedimenting chamber, 12 by 8 inches, equipped with an inverted copper syphon tube, $1^{11}/_{16}$ inches in diameter. This syphon is equipped with four arms; each arm has three holes in its upper surface, making a total of twelve to draw off the supernatant liquid above. The decantation holes in the cross arms are $^{3}/_{8}$ inch above the surface of the arms. An inverted, truncated cone, made of thin copper with a slope of a little more than 25°, fits on the rim of the sedimentation chamber and causes the thin slurry sample to flow out on the surface of the water in the chamber. The syphon tube is raised and fastened so that there is a distance of exactly 10.5 inches from the inside rim of the inverted, truncated copper cone to the level of the decantation holes. This apparatus is shown in Fig. 1.

IV. Procedure

Two commercial feldspars and a standard potter's flint were fractionated. The apparatus was filled with distilled water to a level slightly above the desired mark. The deflocculant, Daxad No. 23,* was added to the amount of 1% of the weight of the powder sample used.

In dispersing the sample, water with dissolved deflocculant was drawn from the sedimentation vessel with a pipette and mixed in a beaker with the dry sample. The water-powder sample ratio must be at least 2.5 to 1 because the slurry introduced otherwise would be very thick and heavy and would settle as globules instead of as individual particles. The test sample was stirred vigorously for about 5 minutes and was introduced on the surface of the water in the settling chamber by pouring it evenly from a beaker onto the surface of the inverted truncated cone, using a wash-bottle to wash out the beaker and to wash the material from the cone. Between 15 and 20 seconds are required for this, and the time is noted as soon as the sample has been introduced. The rubber stopper is removed at the required time from the long arm of the syphon, drawing off the supernatant liquid. The sediment with the liquid which remains above is transferred to a shallow pan, allowed to stand a sufficient length of time, transferred to a beaker by wet washing, and is again sedimented. In each resettling, the deflocculated liquid is replaced.

FIG. 1.—Sedimentation apparatus with the tank removed to show the design.

This process was repeated twice on the same sample, making a total of three sedimentations to get a reasonably clean separation. This may be due to (1) the dragging down of small particles by the larger ones, (2) the settling of small particles below the decantation level owing to momentum acquired during decantation, and (3) turbulence caused when the sample is introduced.

Samples, ranging in size from 20 to 100 grams, were used. The smaller samples, i.e., from 20 to 40 grams, yielded the most accurate fraction separations. The effect of the size of sample is shown in Table I.

In the fractionation of the flint, 40-gram samples were used and each was settled three times; 20-gram samples of feldspar were used, and each was settled four times for a more accurate separation.

* Dewey and Almy Chemical Co.

TABLE I

EFFECT OF SIZE OF FLINT SAMPLE ON SEPARATION WITH REPEATED SEDIMENTATIONS (5 MIN. SETTLE)

Flint sample (gm.)	Sedimentation No. (weight %)					
	(1)	(2)	(3)	(4)	(5)	(6)
100	54.2	41.4	36.4	33.1	31.6	30.3
60	49.5	39.1	35.4	32.0	30.8	29.8
40	48.0	38.6	35.1	31.8	30.6	29.6
20	46.9	37.6	34.1	31.2	30.1	29.2
10	46.4	37.4	34.0	30.9	29.9	29.1

V. Calculations

The decantation holes occupy 0.6% of the total settling area, which makes it necessary to apply this correction as many times as the sample is sedimented to correct for the material which settles in the holes. The percentage weight of each sediment is obtained by the following equation:

$$\frac{\text{Dry sediment weight}}{\text{Sample weight}} \times 100.$$

The percentage of each fraction is obtained by subtracting the percentage weight of one sediment from that which follows.

The data on standard potter's flint and two commercial feldspars are given in Table II.

VI. Discussion and Results

The results are reproducible within 1% with the same size sample and within 2.5% with samples of variable size in the range of 10 to 100 grams.

Little difference was found in the distribution curves of the potter's flint and of the two commercial feldspars. The potter's flint, however, was slightly coarser over most of the size range.

A successful separation of material finer than 10 microns from the coarser material requires about five hours, and fractionation at 20 microns requires about 2 hours. The time necessary to obtain a complete size-distribution curve depends on the number of fractions into which the range is divided.

The sedimentation analysis in the coarser fractions yields nearly twice the quantity of coarse material obtained with the screens on wet analysis, which emphasizes the effect of particle shape and the inaccuracy of screen analysis.

TABLE II

SCREEN AND SEDIMENTATION ANALYSES

Standard potter's flint					
Screen analysis (wet)			Sedimentation analysis		
Diameter (microns)	Standard screen	Weight (%)	Time (min.)	Diameter (microns)	Weight (%)
74	200	2.2	2	>49.8	20.3
74–53	270	3.4	2– 3	49.8 –40.6	6.8
53–43	325	9.7	3– 5	40.6 –31.4	9.9
			5– 7	31.4 –26.6	6.9
>43		15.3	7– 9	26.6 –23.4	3.4
			9–15	23.4 –18.2	7.8
			15–30	18.2 –12.8	9.4
			Hours		
			1/2– 1	12.8 – 9.08	6.1
			1– 3	9.08– 5.24	8.3
			3–20	5.24– 2.00	6.0
			+ 36 min.		
				<2.00	15.1
No. 42 feldspar*					
74	200	0.78	2	>51.2	17.5
74–53	270	3.0	2– 3	51.2 –41.8	6.7
53–43	325	12.0	3– 5	41.8 –32.4	6.2
			5– 7	32.4 –27.4	6.7
>43		15.8	7– 9	27.4 –24.2	3.2
			9–15	24.2 –18.7	7.9
			15–30	18.7 –13.2	12.8
			Hours		
			1/2– 1	13.2 – 9.36	6.0
			1– 3	9.36– 5.40	9.6
			3–21	5.40– 2.00	8.3
			+ 55 min.		
				<2.00	15.1
No. 54 albite feldspar*					
74	200	0.80	2	>50.5	18.1
74–53	270	3.70	2–5	50.5 –31.9	13.8
53–43	325	12.5	5–15	31.9 –18.4	20.8
			Hours		
			1/4– 1	18.4 – 9.22	16.7
>43		17.0	1–21	9.22– 2.00	18.1
			+ 4 min.		
				<2.00	12.5

* Golding Sons Company.

DEPARTMENT OF CERAMIC ENGINEERING
OHIO STATE UNIVERSITY
COLUMBUS, OHIO

Forward-going aggressive ceramists succeed only by continually studying, not narrowly, but broadly, the current problems in all ceramic fields.

THE AMERICAN CERAMIC SOCIETY

is organized cooperation *of, by,* and *for* ceramists.

Most ceramic firms and persons are progressive, clear thinkers and would be supporting this SOCIETY, if and when solicited.

CERAMIC HISTORY

THEODORE AMASA RANDALL, 1857–1926

Organizer and for Forty Years Secretary of the National Brick Manufacturers' Association

Early Life

Theodore A. Randall was a "Buckeye" by birth, having been born in Akron, Ohio, June 11, 1857. His parents moved to Utica, New York, where his early boyhood was spent, and many were the tales he could relate of life along the old Erie Canal. When he was thirteen years old his parents moved to Indianapolis, Indiana, where he was educated. In his early business life, he was an accountant in his father's office and later cashier of the Indiana Agency of the New York Life Insurance Company, from which he severed his connection in 1884. In the same year, together with J. J. W. Billingsley, his father-in-law, and with Frank W. Patton, he started the publication of *The Clay-Worker*, the first clay trade journal in the United States. Theodore A. Randall was editor-in-chief, business manager, and principal owner of *The Clay-Worker* from the beginning in 1884, and during his forty-two years of earnest effort, he established and maintained his paper as a recognized authority in the clayworking industry of the world.

The esteem in which he and his works are held are best set forth in the following excerpts from the National Brick Manufacturers' Association reports after his death.

Presentation of Engrossed Memorial*

GENERAL EDWARD ORTON: "Mr. President, and members of the National Brick Manufacturers' Association, ladies and gentlemen, and members of the Randall family: My duty on this occasion is that of the presentation of the Memorial from this Association to the Randall family, and that duty is not a simple one for in the very nature of the case it calls for a firm grip upon one's feelings.

"I think of Theodore Randall in two ways—from the standpoint of his public service and as a friend—and I want to say a few words about his public service.

The thing that is outstanding in connection with Mr. Randall's work is the fact that he founded his work upon the most enduring thing we have in all human history. If you will look up the lists of people who, in the centuries which have rolled by, have left their name and imprint upon society, you will find that nearly always it was because of human service. There have been men who were great wits, the play of whose fancy charmed and attracted everyone who heard them. You may perhaps find their autobiography written in books. Occasionally someone gets the book and looks up some sharp, brilliant saying, but have the wits of the world directed our destinies? You will find some who have made their mark upon the world as great writers; you will find others in many other capacities of life, but the great figures in history, beginning with Jesus Christ and coming on down the centuries, have been *the men who dedicated their lives to the service of other people.*

"In visioning the life of Theodore Randall and his career, it was largely conducted on this idea of service. He was of service to mankind. Some of us feel that our opportunities in life are not good, that we do not command the proper audience, or that we do not have a message reaching out to a sufficient number of people. This is a superficial view; service begins first with your neighbor who is at your side. Insofar as a man is able to serve those about him, he is able to serve an increasing number. Mr. Randall began serving a limited group of brick manufacturers, but who is to say that his influence in the latter years of his life was confined to a little group. His influence reaches out, as a pebble thrown into a pool, in all directions.

"As an organizer of industry, he had this vision of service as an educator. When, in 1894 at the annual convention of this Association, I discussed the National Brick Manufacturers' Association as an educational institution perhaps it had not been thought of as measuring up to that title, but I think I made it clear that it was nothing more or less than an educational institution. In that sense, Mr. Randall was an educator, because he was constantly waging a fight to bring men together. He was the vehicle—the medium by which they came in contact with a broader life and a broader outlook.

"I do not wish to make the presentation of this Memorial until I have paid my own personal tribute to Theodore Randall. I want to tell you what I personally owe to him. It was in 1894 that I first knew him. He did not know me. I came to him with an idea that was novel. The least you could say for it was that it was a very experimental proposition. I craved the time of the Convention to present the idea of education for clayworkers and to find a means of developing our industry more specifically through education. This idea had scant following at that time, and I found that it was usually received with contumely and amusement and little serious thought. Mr. Randall, without seeing me or without knowing me, gave me an opportunity to present this idea to the largest body of men in the United States which could by any conception be considered a receptive audience in this field. He not only gave me a part of the time of that Convention, but he took me in, in so lovable a manner and brought me in contact with the men whose names were names to conjure with, the men who had the power and influence at that time, so that I went away from that Convention elated and happy, uplifted. He gave me the courage to go ahead and do my work, and what more can be said of any man than that. He had the power and influence to do that thing, and he used his influence and power to produce good results.

* From "The Official Report of the National Brick Manufacturers' Association, Forty-first Annual Convention January, 1927," pp. 8 to 20.

"I always found Theodore Randall of the same mind concerning the things I happened to be working with. In other words, co-operation for a long period of years has been unmarred by personal difference. We did not always see things alike, but we were always able to speak with full tolerance and affection of the other's actions. These are precious things, verily good things to cherish.

"I cannot refrain from mentioning the good fellowship of this man, Theodore A. Randall. I can never forget how he came out to my laboratory one day at the noon hour. I said, 'Will you stay and have lunch?' 'Oh, yes,' he said. I said, 'You had better be a little cautious about accepting.' He said, 'Why?' I replied, 'When you see what I am going to give you for lunch you may not care to stay.' He said, with his characteristic smile, 'If you can live on it all the time, I can live on it once.' So we went in, and I gave him the tag end of a loaf of rye bread, so hard I had to use a monkey wrench to break it, and a stein of tea. Well, I did not hear the last of rye bread and tea for a great many years, but it was the charming way in which he accepted the hospitality, making fun of it as he accepted it, telling others about it as the years passed, always referring to it in a most affectionate and friendly way—this is a sample of the thing that lay back of his contacts not only with myself but with others.

"This memorial resolution is the work of a committee appointed by the president of this Association on the day of the funeral of our departed friend. Among the members of that committee are many of the strong and long-cherished friends of this body. They gave due thought to their task; they set in this document, necessarily brief in form, their choicest thoughts; they framed it in gold. They desire it to be accepted and cherished by the Randall family as a visible expression of our feeling. They have tried to enshrine in this simple way the feelings which we as an Association entertain toward the memory of Theodore A. Randall."

"IN MEMORIAM"

The National Brick Manufacturers' Association of The United States of America hereby records its tribute to the memory of Theodore A. Randall, organizer and for forty years Secretary of the Association.

Theodore A. Randall has passed on. From a life replete with all that makes human existence inspiring and ennobling, he has gone to the rewards which come to those who have served faithfully and well in this brief span of mortal existence. His passing leaves us bereft for the moment, but rich in memories which time will not efface so long as one of us remains.

It is given to few men to influence others as Randall did. By his kindly leadership, his active sympathy, and his firm optimism, he brought together into bonds of enduring accord a great group of men who previously had little known the joys of co-operative effort and unselfish sharing of knowledge and skill. More than any man of his generation, he was an organizer for progress, a capitalizer of good will, an apostle of friendly co-operation. To him the clay industries of America owe a debt they can never pay.

The intellectual qualities which enabled him to entertain the splendid vision of a united clay industry, awakening and throwing its dormant powers for progress into action, could never have attained their goal had it not been for his still greater personal and moral qualities. His love for his friends, his ever-bubbling sense of humor, and his warm human personality enabled him to convert even hostile natures into friends and supporters.

To his bereft and stricken family, we offer our tender sympathy and the assurance that their loss is also our loss, and that with them we and all the world have been made the richer for the life of Theodore A. Randall.

It is signed by Charles A. Bloomfield, William Conway, W. F. Demuth, George M. Fiske, William D. Gates, William K. Hammond, G. B. Luckett, C. P. Mayer, Edward Orton, Jr., John W. Sibley, Jacob Stocke, Jr., and Jay Terry.

For the Clay Products Manufacturers

R. C. BURTON, Zanesville, Ohio: "Immediately after the organization of the National Brick Manufacturers' Association, Theodore A. Randall and a friend came to my home in Zanesville, where I was only a manufacturer of common brick. We became friends immediately and that friendship has grown with the years. Everywhere I went I heard of Mr. Randall; he was the friend of the brick manufacturers. At that time, some forty years ago, scientific brickmaking was in its infancy. We were all making brick the same as they had been made for centuries past. Little progress had been made at this time. I could not understand why a man of Mr. Randall's ability would take up so primitive an occupation as trying to advance the work of common brickmaking.

"You young men do not understand the condition of the business then. If a man was going to build a fine residence, he would hire some men to come to his farm or his land and make a kiln of brick. It was not an established industry. Evidently Mr. Randall had a vision. I visited him in Indianapolis at his office, and there met his assistant, Miss Wallace, who has remained by his side ever since. I think it is a good thing she was his assistant because she brings his spirit back among us today, which we all appreciate.

"I watched the growth of Mr. Randall's activities. Although I built a half-dozen brick plants before I knew how to make brick, Mr. Randall was with me often; we talked over the progress of brickmaking that grew steadily. Other lines of clayworking plants came into our organization.

"At one time, the sewer-pipe manufacturers were with us. Mr. Randall was just as energetic in throwing his whole soul into their business and helping them in every way he could. That business grew until it was advisable for them to form their own organization. Next came fire brick and fireproofing and hollow brick. They grew to such proportions that they established their organization, and Mr. Randall was with them. There were the face brick men, but before that, we had a number of men of a scientific turn of mind who saw the needs of the clayworkers along the line of higher ceramics. Then we had The American Ceramic Society, in which Professor Orton was of great assistance. He was brought into this by Mr. Randall. So all down the line Mr. Randall has been a helpmate in every way possible that the clayworking industries could ask. He was never sensitive; he was jealous. He was jealous for the clayworking industries. His vision was being realized, and the longer he stayed in this organization of clayworking industries, the more his heart and soul were wrapped up in it.

"I never knew him to slacken. As the field opened up, Mr. Randall opened with it. His vision broadened as the industries grew. His life, his social qualities, and his whole

business career are all the evidence that any of us need to know that it was never a matter of dollars and cents with him. His soul was wrapped up in the business and the desire to help his fellow man. Today he leaves an annuity to the younger generation of clayworkers that we shall never be able to repay, and his family will never in a monetary sense receive anything from it. But it is a wonderful annuity that he has left to the clayworkers of the world.

"I want to repeat again that we were in a primitive state when Mr. Randall came into the field, and his vision was great, never faltering, always staying with this industry.

"I know the inspiration of his life will always be a solace to his family; they never need regret. It will be a wonderful thing for Mrs. Randall and his children to remember."

For the Clay Products Association

ROSS C. PURDY:' 'Mr. President, ladies, and gentlemen: Theodore A. Randall, by service, fashioned his own memorial. It is not in an isolated park set aside for the dead, to crumble and be forgotten, but his memorial is in the minds and hearts of his contemporary ceramists and in ceramic history. With increasing glory and appreciation, his work of service will be felt and known by generations of clayworkers not yet born. Nothing that we can say here will add to the memorial which he has himself built. It is our privilege, however, as his contemporaries, to acknowledge and to record our appreciation.

"Associations do not result from a recognized need. Co-operation is not natural. Welfare enterprises always have and probably always will require the same sort of constant selling tactics as are employed by merchants. No matter how fraught with benefits, no issue will be considered and no organized attempt will be made to secure the benefits unless some one person will devote his talents and time to persuading potentially interested persons to join in support. No church, school, fraternal order, or club—no political, charitable, or business organization will originate or continue without it be the business of some one person continually to prompt and lead.

"It is hard to learn that it is in law we have the maximum of liberty, peace, and prosperity and that the most fundamental law, given emphasis to by Christ, is bound up in that beautiful word "fellowship." Federated fellowship is as profitable in business and in manufacturing as it is in the spiritual and intellectual affairs.

"Civilization, i.e., man's capacity to enjoy and profit, is advanced only to the extent that men will federate in fellowship. Big business enterprises are coming to a realization that their welfare is lessened or enhanced in unison with the welfare of all the concerns engaged in like business. Big business has learned that one's biggest competitor is self and that the well being of one's fellow manufacturers is a matter of mutual concern. This is perhaps less evident in business than in other human affairs, but nevertheless it is true in business.

"Daring, great energy, and special talent were required of Theodore A. Randall to persuade competing brickmakers to associate together for the purpose of exchanging information on the economic problems of brick production. And although launched with the enthusiastic active support of the leading brick manufacturers, the National Brick Manufacturers' Association would not have continued a single year had its members not been constantly urged. Progressive projects with most evident benefits accruing would not alone have kept the brick manufacturers in the Association.

"In prompting brick manufacturers to affiliate for mutual benefit and to continue this organized affiliation for forty years was a large task. The National Brick Manufacturers' Association was the first national organization of ceramists. There were State organizations, notably the Illinois Clay Workers' Association, but the fifty or more years of uninterrupted federation of the Illinois Clayworkers' does not in the least lessen the munificence of the monumental service rendered by Theodore A. Randall as promoter and, for forty years, the prime activator of the National Brick Manufacturers' Association. His forty years of service with the N.B.M.A., crystallized and made permanent as it is in the several trade associations and in The American Ceramic Society, will continue with reflected honor to him and with benefit to posterity."

ACTIVITIES OF THE SOCIETY

NOMINATIONS FOR ENAMEL DIVISION OFFICERS

The Enamel Division members will vote on the names of the following persons as officers of the Division for 1940–1941:

Chairman: J. D. TETRICK, Baltimore Enamel & Novelty Co., Baltimore, Md.

Secretary: D. G. BENNETT, Mellon Institute, Pittsburgh, Pa.

Nominating Committee: R. L. FELLOWS, Chicago Vitreous Enamel Product Co., Cicero, Ill., and R. R. DANIELSON, Metal & Thermit Corp., Carteret, N. J.

Councillors: W. H. PFEIFFER, Engineering Lab., Plant 2, Frigidaire Div., General Motors, Dayton, Ohio, and R. D. COOKE, 237 E. Cass St., Joliet, Ill.

—D. G. BENNETT, *Secretary*

42nd ANNUAL MEETING—TORONTO—April 7–13 (1940)

TO CERAMIC CAMERA CLUB MEMBERS

A member of the Board of Control of the Ceramic Camera Club, John R. Hostetter, has left Corning Glass Works and has joined the staff of the publication, *Glass Industry*, in New York, N. Y. The members of the Camera Club extend their congratulations to Mr. Hostetter on this new association.

Get those salon prints ready now for April.

INTER-SOCIETY COLOR COUNCIL

The Ninth Annual Meeting of the Inter-Society Color Council is to be held jointly with the Optical Society of America and the American Physical Society, February 21–24, 1940, in New York City. The technical session is to be co-sponsored by the Technical Association of the Pulp and Paper Industry and will be held on February 21 during its annual meeting at the Roosevelt Hotel.

Members of all member bodies, and any others interested in color, are invited to attend the sessions.

THE TORTOISE WON SLOWLY BUT BY PERSISTENCY

THIS IS NO JACK RABBIT RECORD

■ **With all resignations subtracted and the count made from the cards of those who have paid in full, here is the record as of January 22, 1940**

PAID MEMBERSHIP RECORD

Date of Record	Members Paid		Deferred	Subscriptions	Monthly Sales	Total Circulation
	Personal	Corporation				
December 10, 1936	1452	196				
December 22, 1937	1713	220	12	523	220	2688
December 19, 1938	1815	222	26	589	220	2872
December 19, 1939	1876	237	27	642	220	3002
January 22, 1940	1930	244	23	656	220	3073

■ **A gain of only TWENTY-TWO (22) CORPORATION MEMBERS during 1939. This gain could have been**

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if the Personal Members had sold Corporations on the value of the ceramic research and education promotion program of

THE AMERICAN CERAMIC SOCIETY

ROSTER OF CORPORATION MEMBERS

Abbé Engineering Co., New York, N. Y.
Abingdon Sanitary Mfg. Co., Abingdon, Ill.
A C Spark Plug Co., Flint, Mich.
Akron Porcelain Co., Akron, Ohio
American Gas Assn., New York, N. Y.
American Lava Corp., Chattanooga, Tenn.
American Nepheline Corp., Rochester, N. Y.
American Potash & Chemical Corp., New York, N. Y.
American Refractories Institute, Pittsburgh, Pa.
American Rolling Mill Co., Middletown, Ohio
American Stove Company, St. Louis, Mo.
Amsler-Morton Co., Pittsburgh, Pa.
Anchor Hocking Glass Corp., Lancaster, Ohio
Arketex Ceramic Corp., Brazil, Ind.
Armstrong Cork Co., Lancaster, Pa.
Atlantic Terra Cotta Co., Perth Amboy, N. J.

Babcock & Wilcox Co., New York, N. Y.
Ball Brothers Co., Muncie, Ind.
Baltimore Enamel & Novelty Co., Baltimore, Md.
Bausch & Lomb Optical Co., Rochester, N. Y.
Belden Brick Co., Canton, Ohio
Binghamton Brick Co., Inc., Binghamton, N. Y.
Blue Ridge Glass Corp., Kingsport, Tenn.
Blythe Colour Works, Ltd., Cresswell, Stoke-on-Trent, England
Bonnot Company, Canton, Ohio
Braun Corp., Los Angeles, Calif.
Brockway Glass Company, Inc., Brockway, Pa.
Buck Glass Company, Baltimore, Md.
Buffalo Pottery, Buffalo, N. Y.

Camp Brothers Company, Mogadore, Ohio
Canadian General Electric Co., Ltd., Peterborough, Ontario, Canada
Canton Stamping & Enameling Co., Canton, Ohio
Carborundum Company, Niagara Falls, N. Y.
Carnegie-Illinois Steel Corp., Pittsburgh, Pa.
Carr-Lowrey Glass Co., Baltimore, Md.
Celo Mines, Inc., Burnsville, N. C.
Central Silica Company, Zanesville, Ohio
Ceramic Color & Chemical Mfg. Co., New Brighton, Pa.
Champion Spark Plug Co., Detroit, Mich.
Chattanooga Glass Co., Chattanooga, Tenn.
Chicago Hardware Foundry Co., North Chicago, Ill.
Chicago Pottery Co., Chicago, Ill.
Chicago Vitreous Enamel Product Co., Cicero, Ill.
Clark, N., & Sons, San Francisco, Calif.
Colonial Insulator Co., Akron, Ohio
Commercial Decal Products, Inc., East Liverpool, Ohio
Coors Porcelain Company, Golden, Colo.
Corhart Refractories Co., Inc., Louisville, Ky.
Corning Glass Works, Corning, N. Y.
Crane Enamelware Company, Chattanooga, Tenn.
Cronin China Co., Minerva, Ohio
Crooksville China Co., Crooksville, Ohio
Crossley Machine Co., Trenton, N. J.
Crossman Company, South Amboy, N. J.
Crown Potteries Co., Evansville, Ind.

DeVilbiss Co., Toledo, Ohio
Dixon, Joseph, Crucible Co., Jersey City, N. J.
Drakenfeld, B. F., & Co., New York, N. Y.
Du Pont de Nemours, E. I., & Co., R. & H. Chemicals Dept., Wilmington, Del.

Edgar Plastic Kaolin Co., Metuchen, N. J.
Electro Refractories & Alloys Corp., Buffalo, N. Y.
Empire Sheet & Tin Plate Co., Mansfield, Ohio
Engelhard, Charles, Inc., Newark, N. J.
English China Clays Sales Corp., New York, N. Y.
Eureka Flint & Spar Co., Trenton, N. J.
Exolon Company, Blasdell, N. Y.

Fairfacts Company, Inc., Trenton, N. J.
Federal Seaboard Terra Cotta Corp., Perth Amboy, N. J.
Ferro Enamel Corp., Cleveland, Ohio
Findlay Clay Products Co., Washington, Pa.
Fords Porcelain Works, Perth Amboy, N. J.
Fostoria Glass Co., Moundsville, W. Va.
Frazier-Simplex, Inc., Washington, Pa.

Garco Products, Inc., Butler, Pa.
Gaynor Glass Works, Salem, N. J.
General Ceramics Co., New York, N. Y.
George, W. S., Pottery Co., East Palestine, Ohio
"Giesche" Fabryka Porcelany Sp. Akc., Katowice-Bogucice, Poland
Gillinder Brothers, Inc., Port Jervis, N. Y.
Gladding, McBean, & Co., Lincoln, Placer County, Calif.
Gleason-Tiebout Glass Co., Maspeth, N. Y.
Great Lakes Foundry Sand Co., Detroit, Mich.
Great Lakes Steel Corp., Detroit, Mich.
Green, A. P., Fire Brick Co., Mexico, Mo.

Haeger Potteries, Inc., Dundee, Ill.
Hall China Company, East Liverpool, Ohio
Hancock Brick & Tile Co., Findlay, Ohio
Hanley Company, Summerville, Pa.
Hanovia Chemical & Mfg. Co., Newark, N. J.
Hardinge Company, Inc., York, Pa.
Harshaw Chemical Co., Cleveland, Ohio
Hartford-Empire Co., Hartford, Conn.
Haws Refractories Company, Johnstown, Pa.
Hazel-Atlas Glass Co., Wheeling, W. Va.
Hommel, O., Co., Pittsburgh, Pa.
Houze, L. J., Convex Glass Co., Point Marion, Pa.
Hygrade Sylvania Corp., Emporium, Pa.

Idaho Fire Brick & Clay Co., Troy, Idaho
Illinois Clay Products Co., Joliet, Ill.
Industrial Ceramic Products, Inc., Columbus, Ohio
Ingram-Richardson Mfg. Company of Indiana, Inc., Frankfort, Ind.
International Clay Machinery Co., Dayton, Ohio
International Smelting & Refining Co., Akron, Ohio
Irish Glass Bottle Co., Ltd., Dublin, Ireland
Ironton Fire Brick Co., Columbia, S. C.
Isolantite, Incorporated, Belleville, N. J.
Iyo Toki Kaisha, Ltd., Kobe, Japan

Jova Brick Works, Roseton, N. Y.

Kaolin, Incorporated, Spruce Pine, N. C.
Kentucky Clay Mining Co., Mayfield, Ky.
Kentucky-Tennessee Clay Co., Mayfield, Ky.
Knowles, Edwin M., China Co., Newell, W. Va.
Kohler Company, Kohler, Wis.
Koppers Company, Pittsburgh, Pa.
Kraftile Company, Niles, Calif.

Laclede-Christy Clay Products Co., St. Louis, Mo.
Lancaster Iron Works, Lancaster, Pa.
Lapp Insulator Co., Inc., Le Roy, N. Y.
Laughlin, Homer, China Co., Newell, W. Va.
Lava Crucible Co. of Pittsburgh, Pittsburgh, Pa.
Lee Clay Products Company, Clearfield, Ky.
Libbey Glass Company, Toledo, Ohio
Libbey-Owens-Ford Glass Co., Toledo, Ohio
Liberty Glass Co., Sapulpa, Okla.
Lindemann, A. J., & Hoverson Co., Milwaukee, Wis.
Locke Insulator Corp., Baltimore, Md.
London Brick Co., Ltd., London, England
Louthan Manufacturing Co., East Liverpool, Ohio
Lynch Corporation, Anderson, Ind.
Lynch, A. J., & Co., Los Angeles, Calif.

Mansfield Sanitary Pottery, Inc., Perrysville, Ohio
Mapleton Clay Products Company, Canton, Ohio
Maryland Glass Corp., Baltimore, Md.
Mason City Brick & Tile Co., Mason City, Iowa
Maxson, Elwyn L., Los Angeles, Calif.
McHose, L. H., Inc., Perth Amboy, N. J.
McKee, Arthur G., & Co., Cleveland, Ohio
Metal & Thermit Corp., New York, N. Y.
Metro Glass Bottle Co., Jersey City, N. J.
Mississippi Glass Co., New York, N. Y.
Mitchell Clay Mfg. Co., St. Louis, Mo.
Moore Enameling & Mfg. Co., West Lafayette, Ohio
Moore & Munger, New York, N. Y.
Mosaic Tile Company, Zanesville, Ohio
Mount Clemens Pottery Co., Mount Clemens, Mich.

National Engineering Co., Chicago, Ill.
National Fireproofing Corp., Pittsburgh, Pa.
National Gypsum Co., Clarence Center, N. Y.
National Industrial Sand Assn., Washington, D. C.
National Lead Co., Brooklyn, N. Y.
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A Faint Heart Never Achieves
He Succeeds Who Determines So to Do

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*Lemmerman, Paul C., Grasselli Chemical Co., 3092 Broadway, Cleveland, Ohio.

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Mink, John D., 455 N. Main St., Dunkirk, Ind.; plant chemist, Hart Glass Div., Armstrong Cork Co.

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Perkins, Harrell L., Savannah, Ga.; general industrial agent, Central of Georgia Railway.

Ritter, Joseph S., Adamston Flat Glass Co., Clarksburg, W. Va.; laboratory and research engineer.

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*Seabright, Edward C., 1116 Lakewood Ave., Detroit, Mich.; enamel supervisor, Electromaster, Inc.

Shattuck, Lucille, 2537 Chamberlain Ave., Madison, Wis.; teacher, Madison Public Schools.

Thomas, M. W., Thomas Alabama Kaolin Co., 2412 Ken Oak Rd., Baltimore, Md.; president.

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(1940)

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Smith, Alfred W., Box 250, Fonda, N. Y. (Trenton, N. J.)

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MINUTES OF MEETING OF THE WHITEWARE RESEARCH COMMITTEE OF THE AMERICAN CERAMIC SOCIETY

The Whiteware Research Committee of The American Ceramic Society met December 4, 1939, in room 301, National Bureau of Standards, Washington, D. C.

The members present were J. R. Beam, *Chairman;* E. H. Fritz, A. V. Bleininger, F. H. Riddle, R. V. Tailby, S. J. McDowell, P. D. Helser, and F. P. Hall; representatives of the National Bureau of Standards were G. R. Shelton, W. W. Meyer, E. N. Bunting, A. S. Creamer, P. H. Bates, T. A. Klinefelter, and R. F. Geller; and guests were N. W. Taylor, E. C. Henry, C. J. Koenig, and Hewitt Wilson. Two members of the committee, F. H. Norton and Edward Schramm, were unable to attend.

Preceding the meeting, a survey of whiteware research currently in progress in the various laboratories and ceramic schools was made. These subjects were classified into (1) Thermal History Problems, (2) Plastic and Casting Properties of Clay, and (3) Miscellaneous Investigations and were used as a basis for a round-table discussion. This report, compiled from briefs submitted by twelve institutions together with the work at the National Bureau of Standards, covers the field of whiteware ceramic research.

Thermal History Problems

The forenoon session of the meeting was devoted to reports and discussions of problems dealing with thermal history and was led by F. P. Hall,[1] who presented a résumé of available information on the relation of thermal history and physical properties of ceramic products with resistance to thermal shock. Dr. Hall suggested that thermal conductivity be considered, at least tentatively, as a factor. A substantial majority of the Committee recommended that the National Bureau of Standards undertake an investigation of the factors determining the resistance of ceramic whiteware to thermal shock. A. V. Bleininger suggested that the Bureau develop a so-called practical method and appropriate apparatus for conductivity tests, and N. W. Taylor called attention to the A.S.T.M. symposium on thermal conductivity (papers abstracted in the *A.S.T.M. Bulletin* for January, 1939).

E. N. Bunting referred briefly to the system PbO–B_2O_3–SiO_2, which has been completed.[2] He also presented a progress report on the study of the PbO–Al_2O_3–SiO_2 system.

The need for a study of temperature viscosity relations in glazes was discussed. This problem has been recommended to the Bureau, but no work has been started. The need for such a study was agreed to be urgent; it would naturally fall into two divisions, viz., (*a*) the relations of viscosity and temperature during initial heating and (*b*) viscosity in the decorating fire.

G. R. Shelton's report on the "Glass Phase in Whiteware Bodies" covered the present status of studies in the K_2O–Al_2O_3–SiO_2 field.

C. J. Koenig[3] showed a number of graphs illustrating the thermal expansion of potash feldspar and of nepheline syenite, both as glass and in the crystalline form. The expansion of nepheline syenite is typically the lower for the two materials.

R. F. Geller discussed the results of a short study in progress on the linear changes occurring in clays and body mixtures during the initial heating. Observations are made over the range from room temperature to a maximum of 1250°C.

[1] F. P. Hall, "Fundamentals of Thermal-Shock Resistance," presented at the Joint Autumn Meeting, White Wares and Materials and Equipment Divisions, September 15, 1939, Uniontown, Pa.

[2] R. F. Geller and E. N. Bunting, "System PbO–B_2O_3–SiO_2," *Jour. Research Nat. Bur. Stand.*, **23** [2] 275–83 (1939); R.P. 1231; *Ceram. Abs.*, **18** [11] 312 (1939).

[3] See "Uses of Nepheline Syenite in Some Ceramic Wares," *Ohio State Univ. Eng. Expt. Sta. Bull.*, No. 104.

Plastic and Casting Properties of Clay (Afternoon Session)

A communication from F. H. Norton outlined a proposed study of the plastic and casting properties of clays to be conducted at the Massachusetts Institute of Technology. "It is proposed to carry out a systematic study of ceramic clays, particularly in regard to their use in plastic bodies and casting slips. 'Tailor-made' clay is going to be one of the most important advances in ceramics in the next few years and some of the specifications which would certainly be necessary are (1) type of clay mineral, (2) particle-size distribution, (3) particle shape, (4) amount and kind of adsorbed ions, (5) the nonclay minerals, and (6) amount and kind of organic matter.

"Such a program is being started in our laboratories during the spare time of our regular staff, but progress under these conditions is rather slow. If a contribution could be secured from progressive clay producers and clay users, we could form a fund to carry out this research. The results would be made available to the individual contributors, although it is probable that later many of the results could be published. These results will form a fundamental background on which the individual plants may build the more concrete phases of the subject.

"The following program is suggested as a working outline for this general research, viz., (1) to determine whether the properties of the clay can be positively fixed by controlling the factors previously mentioned; (2) to determine the physical properties of a single type of clay with varying distribution of particle sizes; (3) to determine the influence of adsorbed ions on the plastic and casting properties of controlled clay fractions, extending the work which we have already done in this field to other types of adsorbed ion to enable more general conclusions to be reached; (4) to study the influence of small additions of the finer clay minerals to controlled kaolinite fractions in relation to the physical properties of the clay; (5) to study a prepared fraction of kaolinite when various types and amounts of organic matter, such as lignite extract, humic acid, tannic acid, etc., have been added to it; and (6) to study the nature and action of deflocculants on casting slips made from carefully controlled kaolinite fractions; we do not now have a clear picture of the nature of the deflocculating action. It is hoped that a research of this type will throw light on the whole casting problem."

W. W. Meyer reported on the study of ball clays in progress.[4]

E. C. Henry discussed work on two subjects, viz., "Electric Charges of Clay Particles by Electrophoresis Techniques," and "Effect of Cations on Workability of Clay Using a Machine Which Is a Modification of the Endell Type." The effect on viscosity of Na ions added in varying concentrations to electrodialized clay slips was shown by graphs. Some values of the effect of Na, K, and H ions on shrinkage were presented as well as their effect on the "workability" of plastic mixtures. The latter property is being determined with the Endell "squeeze-and-twist" apparatus. Observations will be amplified to include the effects of other ions.

N. W. Taylor gave a summary of results on the purification of ceramic materials by frothing to be applied, if possible, to certain Pennsylvania clays. These data should be especially applicable to the beneficiation of clays containing nonmagnetic forms of Fe. Dr. Taylor cited as examples: (1) a sand in which the Fe content had been reduced to 0.016%; (2) a nodular flint clay in which the iron had been reduced from 1.79 to 0.42% with a clay loss of 4%; and (3) a white clay in which iron was reduced from 1.76 to 0.69% and titania from 2.37 to 0.36%, with a clay loss of 22%. In this process, the material must be ground fine enough to permit the various minerals present to be separated by suspension.

[4] See *Nat. Bur. Stand. Tech. News Bull.*, No. 270 (October, 1939).

Miscellaneous Investigations

The significance of results obtained by the "moisture expansion test" was presented for general discussion. This method serves as the only known "accelerated service test" for body growth caused by moisture, but it should not be accepted as the only test necessary to predict the life of a ceramic product. If, for instance, the glaze is in compression because of the body contraction caused by cristobalite inversion, it may be several years before the moisture expansion of the body is sufficient to place the glaze again in tension. In the autoclave test at 150 pounds steam pressure (183°C.), however, the body is heated sufficiently to cause reversion of the cristobalite with a resultant body expansion which could cause crazing quite independent of any moisture expansion. Corollary tests, such as thermal shock and the Norton "tuning-fork" method for determining stresses, were recommended. Another factor regarding which there is little written information is the moisture expansion shown by bodies in actual service over prolonged periods of time. Data for a period of one year were published by Geller and Creamer,[5] showing that the effect of steam pressure at 150 lb. per sq. in. for 5 hours might be two to three times more severe than storage for one year in humid air. The relation between the expansions produced by autoclave treatment and by reaction with moisture under simulated service conditions over a period of several years should be investigated.

Hewitt Wilson presented a brief review of the work at the Electrotechnical Laboratory of the Bureau of Mines at Norris, Tenn.; his chief problem is "to find added uses for electricity." Tests on the uniformity of ceramic firing were made in periodic electric kilns of 7-cu. ft. capacity and in a twin-tunnel electric kiln 55 ft. long. In these kilns, where radiation and natural convection alone are the source of heat transmission to the ware, the temperature distribution varies with the rate of heating, the time of "soaking" at the highest temperature, the arrangement of the heating elements, their independent control, the density of the setting, and the distance of the product from the hot elements and from the cold doorways. The distribution under the best conditions is comparable to that found in combustion-fired kilns, but the temperature is more easily controlled in the electric kiln.

Dr. Wilson also outlined a progress report on the study of plate warpage, and he itemized the principal causes for warpage; the investigation of corrective measures is being continued.

On the subject of heating elements for ceramic firing, Dr. Wilson stated, "An average life of 1800 hours, with six of the original fourteen resistors[6] still in service, was obtained in the continuous tunnel kiln. The first of the life test resistors failed after 3120 hours, the second after 3408 hours, and the third after 4872 hours, giving an average of 3800 hours for the three. Permeability tests indicated that the assemblies failed in order of permeability, the most porous failing first, etc. The chief factors contributing to the longer life in this test seem to be (1) fairly gas-tight tubes, (2) precautions and tests to insure gas-tightness of the end assembly, and (3) the larger cross-section area of the graphite terminals, allowing more oxidation to take place before failure occurs.

"One of the most important discoveries made is that oxygen diffuses through the silicon-carbide protection tubes, even against positive internal pressure of other gases, and that tightness of the tube and end seal are apparently more important for long life than the type or amount of protecting gas used. Experiments indicate that 950° to 1000°C. is the minimum safe operating temperature of the graphite resistor in a silicon-carbide protection tube.

"Provisions have been made to operate the continuous kiln, using silicon-carbide resistors (the only commercial nonmetallic heating element on the market at present) equipped with nonwater-cooled terminals to give a comparison with behavior and operating characteristics of the graphite resistor.

"A check at cone 13 down on a 60-hour schedule showed 11.2% less power input with the silicon-carbide than with the graphite resistors, a condition which probably is due to the smaller cross section of the graphite terminals which allow a relatively low heat transfer through the terminals.

"At 1176 hours, the silicon-carbide resistors showed an average resistance increase of 46.9%; this study is being continued."

Dr. Wilson said, in closing, "The study of American clays for sanitary ware has been broadened to include the full-sized tests of sanitary ware and the use of Tennessee and Kentucky ball clays and Georgia and North Carolina kaolins as compared with the English materials. About forty-five different bodies have been made and tested by the usual bar samples and by the manufacture of full-sized sanitary bowls and fountains. The tests are not complete, but the results indicate that certain combinations of kaolin and ball clays will be satisfactory for domestic manufacture.

"The study of large-size sanitary casting has led to more detailed investigation of the dispersion of plastic clay bodies into casting slips and the influence of their soluble salts. Data have been collected on the physical condition of the clay mass after casting against a plaster mold."

Before closing the meeting, attention was called to the "Classification of Ceramic Dinnerware," prepared by A. S. Watts,[7] and reprints of the article were distributed. The members were requested to study this classification from the standpoint of possible conflict with technical or scientific considerations and to be prepared to offer their approval or constructive criticism at the next meeting.

—R. F. GELLER, *Acting Secretary*

[5] R. F. Geller and A. S. Creamer, "Measurement of Moisture Expansion," *Ceram. Age*, **29** [1] 9–10 (1937).

[6] R. E. Gould, M. G. Toole, and M. S. Nelson, "Final Report From TVA Ceramic Laboratories: V, Electric Kilns and Furnaces," *Jour. Amer. Ceram. Soc.*, **22** [7] 220–37 (1939); p. 226.

[7] A. S. Watts, "Classification of Ceramic Dinnerware," *Bull. Amer. Ceram. Soc.*, **18** [8] 314–15 (1939).

Survey of Whiteware Research

Thermal History Problems

(1) "Interface of Matured Glaze and Body," by Paul Buckles, University of Illinois. A graduate thesis, under the direction of C. W. Parmelee, which examines the reactions which take place at the interface when various types of glazes are fired on ceramic bodies at different temperatures.

(2) "Interfacial Reaction Zone Between Certain Glazes and High Talc Bodies," by L. A. Rhoades and P. S. Dear, Virginia Polytechnic Institute.

(3) "Glaze Fit," by W. C. Bell, Engineering Experiment Station, Ohio State University. An evaluation of the glaze fit methods so far proposed. The character of the glaze, the glaze composition in relation to final strength, glaze compression or tension relation to the strength of the fired ware, and glaze hardness relation to the strength of the fired glaze are evaluated.

(4) "Volatility of Some Glaze Constituents," by W. Curtis and S. Stanislaw, New York State College of Ceramics. Problem to be accomplished by means of the spectroscope.

(5) "Effect of Various Compounds on Volatility of Glazes," by W. Kunes and B. Gentsch, New York State College of Ceramics. Problem to be accomplished by means of the spectroscope.

(6) "Glasses Formed by Mixtures of Feldspar with the Different Alkaline Earths and Combinations of Same," Ohio State University. Includes potash, soda and soda-potash feldspars, and their incorporation in semivitreous and vitreous bodies.

(7) "Effect of Oxidation and Reduction on Vitrification of a Vitreous Whiteware Body," Experiment Station, New York State College of Ceramics.

(8) "Influence of Firing and Cooling Curve on Character and Properties of Vitreous Ceramic Bodies," Ohio State University. A continuation of a similar study on semivitreous bodies.

(9) "Whiteware Bodies Containing Feldspar, Steatite, and Zircon Silicate," by S. Fossaceca, New York State College of Ceramics.

(10) "Eutectic Aluminosilicate Glasses in Glazes," Ohio State University.

(11) "Eutectic Borosilicate Glasses in Glazes," Ohio State University.

(12) "Varying Amounts of Talc Between 60 and 90% on a Pressed Whiteware Body," by L. M. Showalter and P. S. Dear, Virginia Polytechnic Institute.

(13) "Nepheline Syenite," by C. J. Koenig, Engineering Experiment Station, Ohio State University. Deals with the development of ceramic bodies for use in vitreous tableware, sanitary ware, electrical porcelain, semivitreous ware, and enamels. These bodies have been worked out at the Station and have been tried out at various plants. Preceding this work, properties of nepheline syenite, such as its relation to glaze fit, maturing of the body, translucency, warpage, and ring, were established. (See C. J. Koenig, *Jour. Amer. Ceram. Soc.*, **22** [2] 35–38; [2] 38–46 (1939). Another paper by Dr. Koenig on the use of syenite in floor- and wall-tile bodies will be published in March, 1940, in *Jour. Amer. Ceram. Soc.*)

(14) "Wollastonite in Whiteware Bodies," by R. Brownell, New York State College of Ceramics.

(15) "Nepheline Syenite in White Artware Bodies Below Cone 11," Ceramic Art Dept., Ohio State University.

(16) "A One-Fire Whiteware Body at Cone 1," Ceramic Art Dept., Ohio State University.

(17) "Use of Zoisitic Aplite in Floor-Tile Bodies," by J. F. Wright, P. S. Dear, and J. W. Whittemore, Virginia Polytechnic Institute.

(18) "Mineralogical Investigation of Chrome-Tin Pinks and Ceramic Stains," by P. G. Herold, *Missouri School of Mines Bull.*, **13** [2] (May, 1939).

(19) "Development of Chrome-Tin Reds," by D. Thomas, New York State College of Ceramics.

(20) "Influence of Uncommon Minerals Substituted in Typical Two-Fire Vitreous China Body," by G. M. Colucci, New York State College of Ceramics.

(21) "Titanium Stains for Whiteware Bodies," by E. Thomas, New York State College of Ceramics.

(22) "Use of Lepidolite as a Flux in Whiteware Bodies," Experiment Station, New York State College of Ceramics.

(23) "Electric Porcelain Bodies of Clay Talc and Magnesia Mixtures," Experiment Station, New York State College of Ceramics.

Plastic and Casting Properties of Clay

(1) "Proposed Programs for Studying Plastic and Casting Properties of Ceramic Clays," by F. H. Norton, Massachusetts Inst. of Technology.

(2) "Electric Charges of Clay Particles by Electrophoresis Techniques," by E. C. Henry, Penn State College. Base-exchange properties and viscous behavior of certain whiteware clays are discussed.

(3) "Effect of Cations on Workability of Clay Using a Machine Which Is a Modification of the Endell Type," by A. Siefert and E. C. Henry, Penn State College.

(4) "Castibility of Clay Slips," by G. A. Loomis, Engineering Experiment Station, Ohio State University. Influence on the castibility of such factors as (1) grain size, (2) pH value, (3) mobility, (4) age, (5) composition and amount of electrolyte, (6) solubie salts, and (7) base-exchange capacity. The ultimate object of this study is to find the best means of stabilizing casting slips and simplifying the problem of their control (to be published in 1940 in *Jour. Amer. Ceram. Soc.*).

(5) "Comparison of Properties of Whiteware Bodies Containing Ball Clay and Those Containing No Ball Clay," Experiment Station, New York State College of Ceramics.

(6) "Study of Dehydration and Rehydration of Clays," by V. D. Fréchette, University of Illinois. Changes which take place in various clays fired at different temperature levels and which are subsequently subjected to conditions which may produce rehydration. The clays which have been selected represent (*a*) high kaolin content, (*b*) high illite content, (*c*) high montmorillonite content. Observations will be made on changes in the physical properties, the glassy bond, and the structural changes.

(7) "Revised Method for Measuring Plasticity of Clays," by J. W. Whittemore, Virginia Polytechnic Institute.

(8) "Effect of Moisture Expansion on Glazes at Elevated Pressures up to 400 Pounds per Square Inch," by R. P. Greenman, New York State College of Ceramics.

(9) "Use and Purification of Southeastern Missouri Cretaceous Clays" Co-operative investigation, Missouri School of Mines, State Geological Survey, and WPA.

(10) "Beneficiation of Various Ceramic Raw Materials by Means of Froth Flotation," by D. W. McGlashan, Penn State College.

(11) "Application of Froth Flotation Technique to Removal of Iron-Containing Minerals," by W. A. Scholes, Penn State College.

(12) "North Carolina Kaolin, Kaomec," by W. H. Earhart, Engineering Experiment Station, Ohio State Univ.

(13) "Use and Purification of Feldspar From Missouri Granite," Co-operative research between Missouri School of Mines, Missouri State Geological Survey, and U. S. Bureau of Mines.

(14) "Comparison of an All-American Clay Body and Bodies Containing English China Clay," by J. Thomas, New York State College of Ceramics.

(15) "Use of Organic Deflocculants for Whiteware Casting Slip," by R. R. Zurer, New York State College of Ceramics.

(16) "Use of Wetting Agents and Other Additions on Properties of a Dry-Mixed Vitreous Body," Experiment Station, New York State College of Ceramics.

(17) "Physicochemical Control of Properties of Clay," by J. D. Sullivan, Battelle Memorial Institute, Columbus, Ohio.

Miscellaneous Investigations

(1) Development of a laboratory tunnel kiln by actual operation of a 36-foot tunnel kiln, Ohio State University.

(2) Pottery project sponsored by Missouri School of Mines, Missouri State Geological Survey, and the WPA for testing clays under actual manufacturing conditions.

(3) "Control of Consistency of Glaze and Similar Slips," by M. K. Blanchard, University of Illinois.

(4) "Control of Glaze Application, 'Irwin' Consistometer," by T. S. Galanis, New York State College of Ceramics.

(5) "Effects of Fineness of Grain of Feldspar and Flint," Engineering Experiment Station, New York State College of Ceramics.

(6) "Garspar as Ceramic Material," by G. J. Bair, Mellon Institute.

(7) "Development of Various Grogs and Sagger Bodies Using Virginia Kyanite," by J. P. Sawyer and J. W. Whittemore, Virginia Polytechnic Institute.

FORTY-SECOND ANNUAL MEETING, APRIL 7–13, 1940

ROYAL YORK HOTEL, TORONTO, CANADA

Program of Research Reports

More than 120 program titles were listed by February 1, 1940.

Have you a paper to present?

SCHOOL NOTES

VIRGINIA POLYTECHNIC INSTITUTE

The Student Branch of the Virginia Polytechnic Institute held its first meeting of the year on October 5, 1939. Thirty-three members were present. This is a decided increase over the membership of nine at the time of its organization in 1935. There are now forty-five students enrolled in Ceramic Engineering.

The officers for this year are *President*, W. H. Hitt; *Vice-President*, O. J. Parker; *Secretary-Treasurer*, K. S. Haff; and *Councillor*, J. W. Whittemore.

Meetings are held on the first and third Thursdays of each month. After the business session, a program is given which usually consists of an informal talk or the presentation of a paper by a member of the Student Branch on some subject related to ceramic engineering. At alternating meetings, pictures pertaining to ceramic industry are shown at which time the meeting is open to the student body. At one meeting this year, pictures of the Pittsburgh Plate Glass Company were shown, and at the last meeting, a smoker for the members was held after the regular session.

—KEITH S. HAFF, *Secretary*

UNIVERSITY OF ILLINOIS ALUMNI

Frederick R. Matson, Jr., who received his B.S. degree in Ceramics in 1933 at the University of Illinois, has been appointed to the position of Assistant Curator in Ceramics at the Michigan State Museum located on the campus at Ann Arbor. After graduating from Illinois, Dr. Matson continued with graduate work in archeology, and he received his Ph.D. degree in June, 1939, from the University of Michigan. During the intervening period, he spent one year in Bagdad on an expedition where he collected material for his thesis. Dr. Matson is using his knowledge of ceramic processes in a study of the technological differences in the pottery manufactured by Indian tribes from various sections of the United States as an aid in the establishment of the cultural development of these peoples. He is also working with ancient pottery, glass, and enamels of Egypt and other archaeologically rich territories.

Fay Tooley was one of the performers on Major Bowes' program on January 4, playing a marimba number. Dr. Tooley is a research engineer at Owens-Corning Fiberglas Corporation and was in charge of the music for the "Fiberglas Frolics," which was presented by employees of that company for a Christmas benefit. He received his Ph.D. in Ceramic Engineering at the University of Illinois in June, 1939. While at Urbana, he was employed by the Illinois State Geological Survey and was a member of the University of Illinois Concert Band.

OHIO STATE UNIVERSITY

The Ohio State University Student Branch of The American Ceramic Society met on January 17 and also on January 20, 1940, in Lord Hall.

At the meeting on January 17, M. C. Shaw of the Edward Orton, Jr., Ceramic Foundation spoke on "Pyrometric Cones." He presented some of the history and developments of the cone industry, explained the difficulties encountered in the use of cones, and indicated solutions of the difficulties. Dr. Shaw also exhibited a chart which showed the maturing temperatures of the cones at slow and high heat rate advances. A discussion period followed the lecture.

On January 20, H. E. Nold, Chairman of the Department of Mine Engineering, Ohio State University, spoke on "A Miner Looks at the Ceramic Industry."

KENNETH E. SMITH TO CONDUCT SUMMER CERAMIC COURSE AT BLUE RIDGE, N. C.

Kenneth E. Smith, Head of the Ceramic Department at Newcomb College, New Orleans, La., will conduct a six-weeks' course in ceramics at Blue Ridge, N. C., from July 22 to August 30, 1940. An electric kiln will be installed and the Hilton Potteries will build a ground-hog kiln for use during the course. Bench whirlers and kick wheels and other ceramic equipment will be available for this work.

Credit for this course will be given through the Y.M.C.A. Graduate School, which is a regular chartered college. Students should be able to transfer credits received in this course to any other school.

A three-hour course will cost $12.00, and an additional $3.00 will be charged for materials. Students may take a double course for the payment of a $20.00 fee.

Ceramic Art Conference

The Ceramic Section of the Art Conference at Blue Ridge, N. C., will be held from July 29 to August 5.

—W. D. WEATHERFORD, *President*

UNIVERSITY OF ILLINOIS ENGINEERING EXPERIMENT STATION

Research Graduate Assistantships

The University of Illinois maintains a number of research graduate assistantships in the Engineering Experiment Station to assist in the conduct of engineering research and to extend and strengthen the field of its graduate work in engineering. The assistantships, for each of which there is an annual stipend of $600 and freedom from all fees except the matriculation and graduation fees, are open to graduates of approved American and foreign universities and technical schools who are prepared to undertake graduate study in engineering, physics, or applied chemistry.

An appointment to a research graduate assistantship is made and must be accepted for two consecutive collegiate years of ten months each, at the expiration of which period, if all requirements have been met, the degree of Master of Science will be conferred. Half of the time of a research graduate assistant (approximately 900 clock hours for each ten-month period) is required in connection with the work of the department to which he is assigned; the remainder is available for graduate study.

Nominations to these positions, accompanied by assignments to special departments of the Engineering Experiment Station, are made from applications received by the Director of the Station each year not later than the first day of March. The nominations, which are made by the Executive Staff of the Station, subject to the approval of the President of the University, are based on character, scholastic attainments, and promise of success in the principal line of study or research to which the candidate proposes to devote himself. Preference is given those applicants who have had some practical engineering experience following the completion of the undergraduate work. Appointments are made in the spring, and they become effective the first day of the following September. Research work and graduate study may be undertaken in ceramic, chemical, civil, electrical, mechanical, metallurgical, and mining engineering, physics, railway engineering, and theoretical and applied mechanics.

The work of the Engineering Experiment Station is closely related to that of the College of Engineering, and the Heads of Departments in the College constitute the Executive Staff of the Station. Investigations are carried on by members of the Station staff, and also by members of the instructional staff of the College of Engineering.

DONALD K. STEVENS HONORED

Donald K. Stevens, sophomore in ceramic engineering at the University of Illinois, was the recipient of the Keramos award, which is a student membership for one year in The American Ceramic Society. Each year the Illinois Chapter offers this prize to the sophomore registered in ceramic engineering who had the highest scholastic standing during his freshman year. Stevens qualified for this honor with a record of 5.0, a perfect A average.

He has shown his scholastic abilities also by receiving the following recognitions: a scholarship to the University offered on a competitive basis by the Illinois Congress of Parents and Teachers, a medal from Sigma Tau for the highest standing among the freshmen in the entire engineering school, and membership to Phi Eta Sigma, honorary University freshman scholastic fraternity. His social and recreational activities are centered in Alpha Phi Omega (service fraternity), Pershing Rifles unit, Men's Glee Club, Y.M.C.A. Freshman Fellowship Committee, and Illustration Editor for the *Technograph*, a student engineering magazine.

Stevens comes from a family of ceramic engineers. His father, Douglas F. Stevens, was formerly associated with the Acme Brick Company of Cayuga, Ind., and is now Research Associate in the Industrial Minerals Division of the Illinois State Geological Survey. A brother, Robert P. Stevens, a member of the class of 1934, is sales engineer with Charles Taylor & Sons, Incorporated, at Cincinnati, Ohio.

CENTRAL OHIO SECTION

Members of the Central Ohio Section held a meeting on January 26 in the executive offices of The American Ceramic Society. During a short business meeting, officers for 1940–1941 were elected as follows:

Chairman: C. J. Koenig, Engineering Expt. Station, Ohio State Univ., Columbus, Ohio.
Secretary: Myril C. Shaw, Edward Orton, Jr., Ceramic Foundation, Columbus, Ohio.

Louis A. Cole, Sales Manager of the Owens-Illinois Glass Co., Newark, Ohio, was the speaker for the evening. His subject, "Glass, Its Development," was illustrated with many exhibits of glass and with various experiments.

Ross C. Purdy, Executive Secretary of The American Ceramic Society, also gave a brief talk on the permanent exhibits of glass in the offices of The Society.

There was an excellent attendance at this meeting, including a number of ladies.

FORTY-SECOND ANNUAL MEETING, AMERICAN CERAMIC SOCIETY

Toronto, Canada, Royal York Hotel, April 7–13, 1940

HOW TO HANDLE CURRENCY EXCHANGE

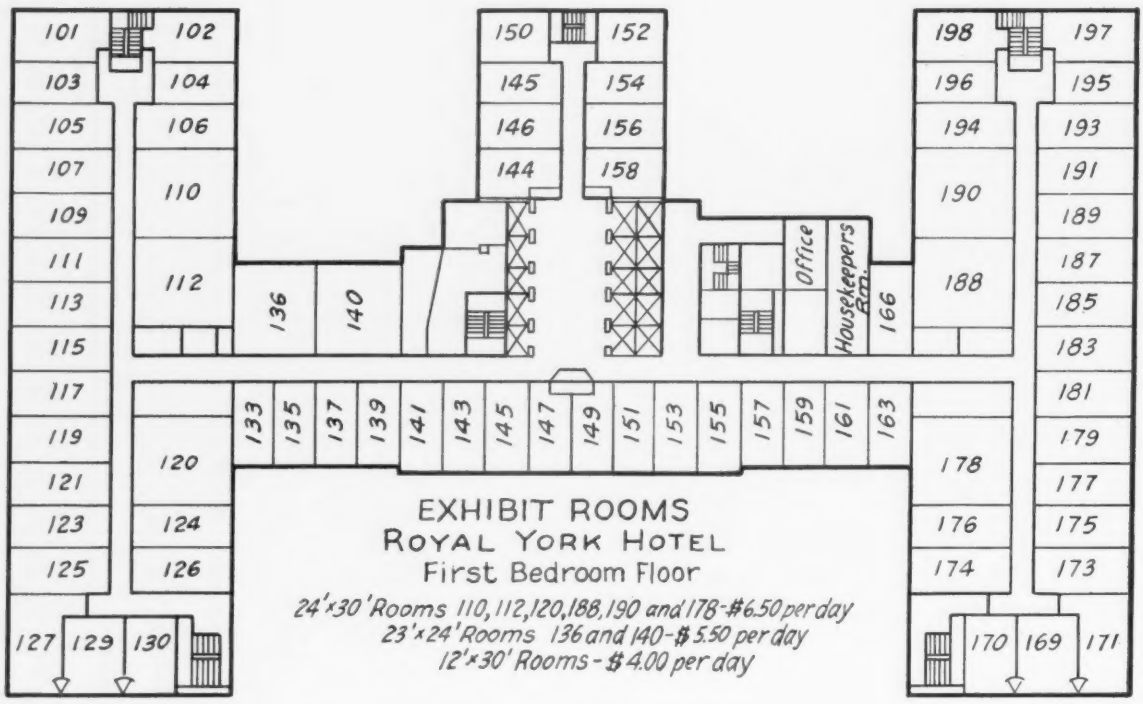
I think you would be wise to advise the members of The American Ceramic Society not to purchase Canadian funds in the United States. They are likely to be charged a heavy service percentage which will prevent them from securing the full benefit of the 10% premium on American funds that now exists in Canada. They may bring in currency, traveler's checks, or they may draw checks upon their own bank accounts and secure this 10% premium at any bank, in any first-class hotel, or at any first-class place of business in the City of Toronto.

(Signed) T. H. R. McNally, *Manager, Toronto Convention and Tourist Association, Inc.*

The exchange control board on January 27 announced a new regulation authorizing merchants, hotel keepers, and other residents serving tourists to accept foreign currency from visitors at the official rates.

It would be advisable for your members to make their exchange in currency here and they will receive 10% on their money. There are banking facilities in the Hotel, and there will be no difficulty whatsoever in this regard. If your registration fees and dues are payable in United States funds, your Society will not suffer any loss.

(Signed) J. Johnson, *Manager, Royal York Hotel*



NOTES

LEA H. HALPERN, DUTCH CERAMIST

I should like to introduce with a few words to your readers our famous ceramist, Miss Lea H. Halpern, who is exhibiting her work under the auspices of the Netherland-America Foundation at the Holland House, Rockefeller Center, New York.

Miss Halpern studied in Vienna with M. Powolny and later in Gouda at the Ceramic Institute of the State of the Netherlands, where she concentrated mainly on the technique of glazes. She has worked since 1929 in her own atelier in Amsterdam.

It is particularly the great variety of beautiful and individual glazes which distinguish her work. The forms are plain, the material is true, and it is never artificial. The measurements and dimensions are always excellent. In everything, you can feel the "potter" in whose hands the clay lives, even in the small animals which she forms naturally between her fingers and in which the character of the animal expresses itself so distinctly.

The artist displays all her knowledge and art in the glazes; plain white and ivory for the vases which are such good containers for flowers; yellow and turquoise, for the perfection of which she worked for years, in the most refined part of her creations; and the china red, the reduction, and craquelé glazes. One is amazed at the new combinations and the richer and deeper effects which appear in every new kiln.

—K. ZIMMERMAN, *Gouda, Holland*

NEW YORK SOCIETY OF CERAMIC ARTS FEBRUARY MEETING

J. Scott Williams will address the New York Society of Ceramic Arts at its meeting at the Metropolitan Museum of Art in New York on February 14. His work has been diverse in character although principally of the decorative type, and he has worked in many mediums, including water colors, oils, enamels, glass, and metals. The range of application of his work has varied from material for books and magazines to the huge vitreous enameled murals which he designed and executed for the Home Furnishings Building at the New York World's Fair. The latter include the largest mural of this type ever produced, measuring 72 feet long by 28 feet high.

Mr. Williams' work in glass and enamels brought him an A.N.A. in 1935 and two years later N.A. in the National Academy. He started handling large mural areas in 1926 and has done outstanding work in this field.

The subject of Mr. Williams' address is "Murals in Vitreous Enamel," and it will be illustrated with about thirty slides of which ten are in color. He will present new ideas as to the methods of applying vitreous enamel to large areas which promise a great advance in the art.

Lawrence E. Barringer is President and Mrs. William P. Willetts is Secretary of the Society.

EARLY GERMAN ART REVIVED; HISTORIC MATERIALS USED BY MRS. KEYSER*

A large pottery platter fastened to a tree under the sign "Brookcroft" is the only indication of the busy doings in the cozy cottage back from the road. Passersby on Butler Pike are attracted by the platter, which looks like an antique Pennsylvania German piece. It is a copy, but so exact that many a caller has been deceived by its quaint charm and has marveled that so handsome a platter would be exposed to the weather. It is only clay to Mrs. C. Naaman Keyser, who fashioned it at her potter's wheel inside the cottage. The living clay, yielding to the pressure of her knowing fingers, alone fascinates her vastly more than the finished work from her firing kiln.

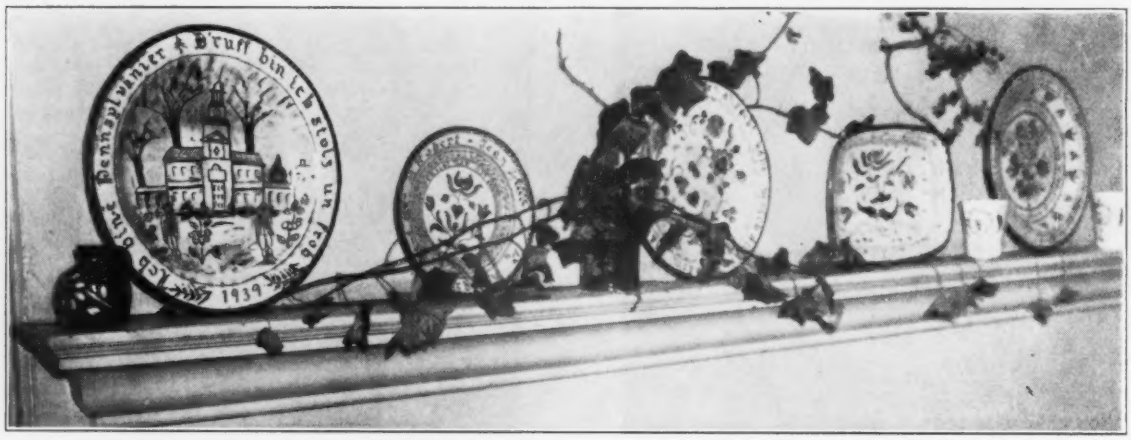
Sgraffito ware. White bowl with red clay bottom, flowers in greens, reds, and blues. The motto on the plate at the lower right reads, "I knew when I saw you, you were a lovely man." The decorations are dark on white slip.

* By Grace Ramey, *Evening Public Ledger*, Philadelphia, Pa., November 25, 1939.

It was only a few years ago that Mrs. Keyser first discovered the soothing charm of the potter's wheel. She was then working in a clinic, where she found that pottery making was a help to mental cases. She became fascinated with the work itself and decided to revive the making of old Pennsylvania German pottery, an art lost since the Civil War. A New Englander herself, she looked at the existing examples of this work with fresh eyes, seeing its beauty and the peculiar charm more clearly than do people brought up where old German antiques and mementos are no great novelty.

prices of imported china. The "heart" motif, a favorite of the Swiss; the tulip (probably from Persia); the favorite bird of Paradise; and other characteristic designs are evident. Many of Mrs. Keyser's platters and plates carry quaint maxims and sayings in Lancaster Dutch. One bears the homely advice, "You can't learn sitting in a rocking chair." Another quotes cynically, "When it rains soup we never have a dish." Another, sentimentally, "This dish and heart shall never part."

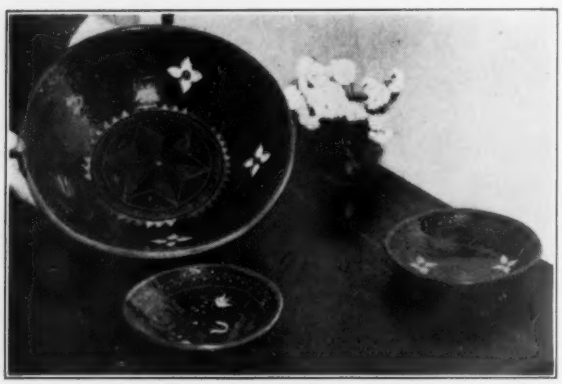
This nearly forgotten art has become vital to Mrs. Keyser. Her face has the serene look of a person beyond



Pennsylvania German pottery; at left is New York World's Fair exhibit plate.

Her Pennsylvania Dutch husband, son of a famous writer on Dutch lore, helped her in her work by furnishing her with data and a background for research. She has scoured the country, visiting old potteries and talking with anyone who could tell her about the old craft. The old molds in her collection are interesting, though hardly more so than the creations of her own wheel, marked with her sign, a pine tree and the letter "K."

The clay used by Mrs. Keyser comes from the same sources as that used by the potters in the early 1800's, rich, dark red for the body of plates and bowls and white for the strange curly designs, as in old slip ware. The simple designs have proper balance, whether they are lines, crude tulips, or adaptations of Hex signs like those on big red barns in the Pennsylvania Dutch farm country.



Polychrome black with high glaze.

In making the more elaborate sgraffito ware, a Pennsylvania black clay is used. The design is dug out and brilliant colored clays are painted in, giving a polychrome effect. The sgraffito, more commonly called tulip ware, is a more refined form of pottery than "slip." It is inspired by household goods brought from European homes in early days and made here perhaps as a protest against the high all the rush and hurry of modern life. She talks of the clay as if it had a personality of its own, speaking sympathetically of a piece that has been overworked and fails to obey her fingers, saying, "It is tired: it will be all right when it has rested." She works each piece with special care before she puts it on the wheel, for a bubble might explode in firing and ruin all the previous work. It is fascinating to watch a lump of the dull red clay take form and shine under her fingers.

Her wheel, the only concession to modernism, runs by electricity, but, as it whirls, the clay seems to obey her wish almost by itself; her fingers press here and there and a bowl appears; another twirl and a tall, fluted vase rises or a more plebeian beer mug.

Recognition for her work has been quick in coming to Mrs. Keyser. Her pottery was exhibited at the World's Fair in 1939, and many of her finer pieces are to be seen in choice collections.

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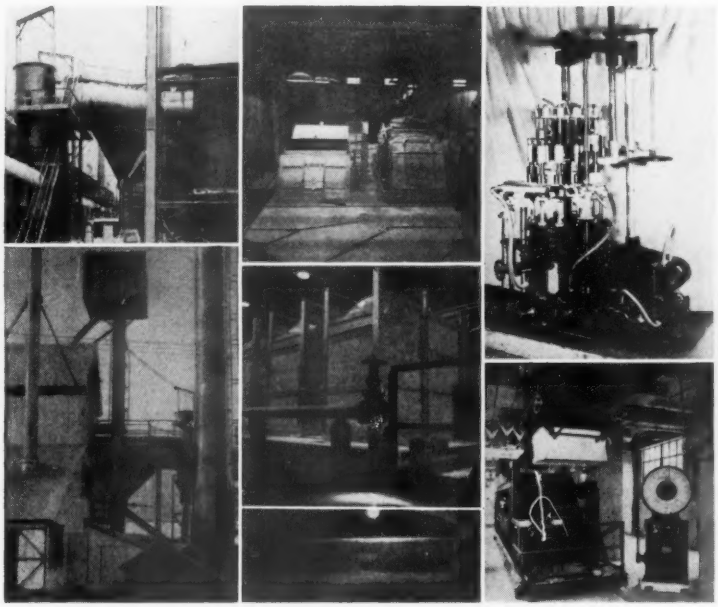

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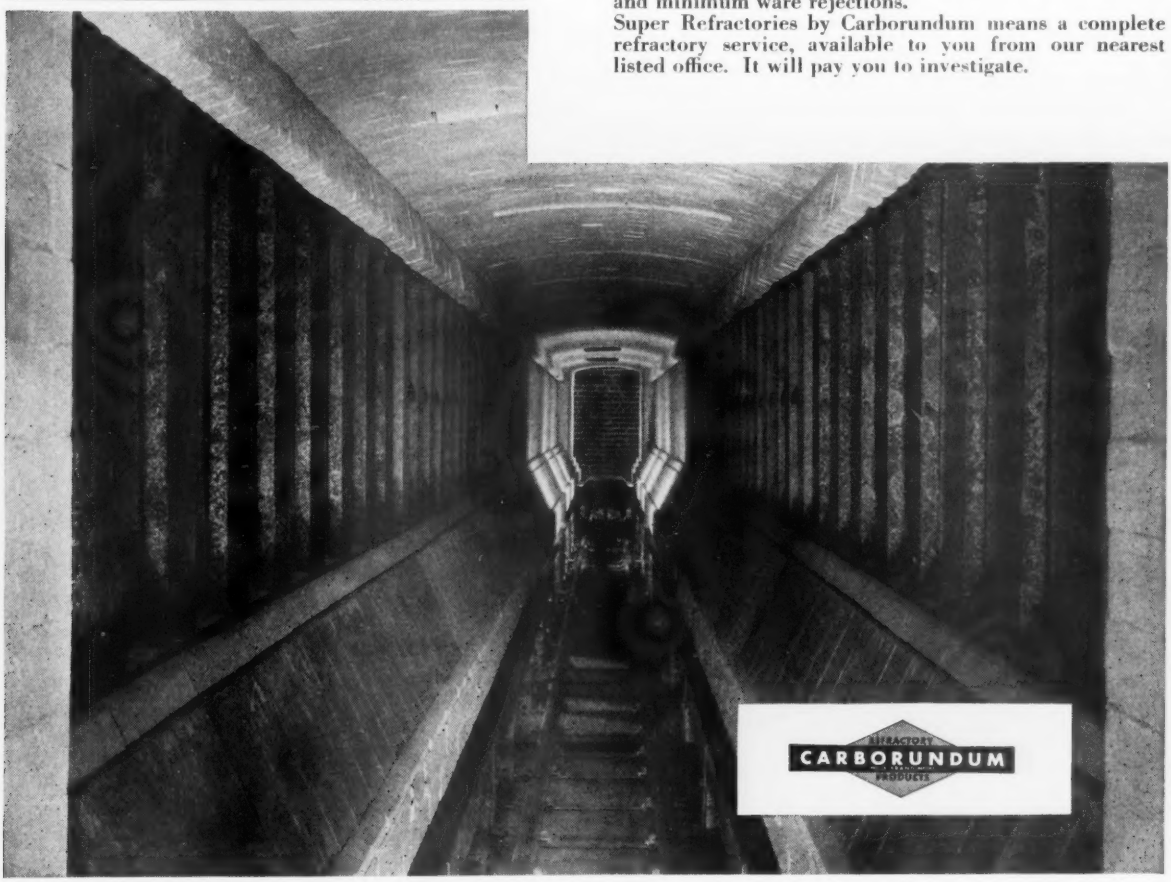

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Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Great Lakes Foundry Sand Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.

Flint Pebbles
Ceramic Color & Chemical Mfg. Co.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
The Vitro Mfg. Co.

Floors (Non-Slip)
Norton Co.

Fluorspar
Harshaw Chemical Co.
The Hommel Co., O., Inc.

French Flint
Maxson, Elwyn L.
Paper Makers Importing Co.

Frit
Ceramic Color & Chemical Mfg. Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Frosting Mixtures
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Fuel Oil Systems and Control, Stokers
Bethlehem Steel Co.
Frazier-Simplex, Inc.

Furnaces
Carborundum Co. (*Carboradiant*)
Denver Fire Clay Co.
Frazier-Simplex, Inc.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Swindell-Dressler Corp.

Furnaces, Enameling
Swindell-Dressler Corp.

Glass Bending Ovens, Glass Decorating Machines
Frazier-Simplex, Inc.

Glass Equipment
Hartford-Empire Co.
Lancaster Iron Works, Inc.

Glass Melting Tanks and Furnaces
Frazier-Simplex, Inc.

Glass Sand
Great Lakes Foundry Sand Co.

Glass Thickness Gauge
Bausch & Lomb Optical Co.

Glaze and Body Spar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Glazes and Enamels
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

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Our complete line of colors and decorations includes every decorating material: standard and special-match colors for ceramics and glassware, precious metal decorations, overglazes, underglazes, color oxides, and other ceramic materials.

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Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Glaze Spar
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.

Goggles
The Hommel Co., O., Inc.
Willson Products, Inc.

Gold
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Gold Decorations
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.

Granulators
Hardinge Company, Inc.
Lancaster Iron Works, Inc.

Grinding Wheels
Carborundum Co. (*Carborundum and Aloxite*)
Chicago Vitreous Enamel Product Co.
Norton Co. (*Alundum-Crystolon*)

Hearths
Carborundum Co. (*Carbofrax* heat treating)
Corhart Refractories Co.
Norton Co. (*Crystolon*)

Hearths (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.
Norton Co.

Hose (Air and Fluid)
The DeVilbiss Co.

Hydrofluoric Acid
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Iron Chromite
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.

Iron (Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.

Iron Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Porcelain Enamel and Mfg. Co.
The Vitro Mfg. Co.

Kaolin
Ceramic Color & Chemical Mfg. Co.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
United Clay Mines Corp.
The Vitro Mfg. Co.

Kilns, China (Decorating)
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Frazier-Simplex, Inc.
The Hommel Co., O., Inc.
Swindell-Dressler Corp.

Kilns- (Electric, Circular, Tunnel)
Swindell-Dressler Corp.

Kiln Furniture (Silicon Carbide, Semi-Silicon Carbide) (Refractory)
Louthan Mfg. Co.

Kyanite
Celo Mines, Inc.

Kryolith (see Cryolite)
Pennsylvania Salt Mfg. Co.

Laboratory Ware
Norton Co.

Lehr Tile (High Aluminous Clay, Electrically Sintered Aluminum Oxide, Silicon Carbide)
Carborundum Co.

Lehrs
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehrs (Electric or Fuel Heated)
Frazier-Simplex, Inc.
Swindell-Dressler Corp.

Lehr Loaders
Frazier-Simplex, Inc.

Linings (Furnace Refractory, Block Refractory Plate, Brick, and Tile)
Carborundum Co.
Corhart Refractories Co.
Denver Fire Clay Co.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.
The Vitro Mfg. Co.

Lithium Carbonate
Drakenfeld, B. F., & Co.
Edgar Plastic Kaolin Co.
Foote Mineral Co.

Lithium Minerals
Foote Mineral Co.

Loaders (Bucket)
National Engineering Co.

Magnesia (Fused)
Norton Co.

Magnesia (Sintered, Calcined)
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Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Porcelain Enamel and Mfg. Co.

Magnesite
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Magnesite Calcined
Foote Mineral Co.
The Hommel Co., O., Inc.

Magnesium Carbonate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Manganese
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Manganese Dioxide
Drakenfeld, B. F., & Co.
Edgar Plastic Kaolin Co.
Foote Mineral Co.

Manganese (Oxide)
Ceramic Color & Chemical Mfg. Co.
Corhart Refractories Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Masks (Breathing)
The DeVilbiss Co.
Drakenfeld, B. F., & Co.

Metals (Porcelain Enameling)
American Rolling Mill Co.
Bethlehem Steel Co.

Micronized Products
Porcelain Enamel and Mfg. Co.

Microscopes (Polarizing)
Bausch & Lomb Optical Co.

Minerals
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Mixers
National Engineering Co.
Ransome Concrete Machinery Co.

Mixers (Batch)
Lancaster Iron Works, Inc.
National Engineering Co.

Mixers (Concrete, Paving, Road Paving, Plaster, Asphalt, Truck, Mortar, Bituminous)
Lancaster Iron Works, Inc.
Ransome Concrete Machinery Co.

Mixers (Laboratory)
Lancaster Iron Works, Inc.
National Engineering Co.

Mold Sanders
Lancaster Iron Works, Inc.

Muffles (Furnace) (Laboratory)
Carborundum Co. (*Carbofrax*)
Denver Fire Clay Co.
Frazier-Simplex, Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.

Mullers (Batch)
Lancaster Iron Works, Inc.
National Engineering Co.

Muriatic Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Pennsylvania Salt Mfg. Co.

Needle Antimony
Edgar Plastic Kaolin Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Nepheline Syenite
Great Lakes Foundry Sand Co.

Nickel Salts
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Nitrates (Cobalt, Sodium)
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Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Nitre
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Norbide (Norton Boron Carbide)
Norton Co.

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Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.

Opacifiers
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Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
Pennsylvania Salt Mfg. Co.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Overglaze Colors
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc. R. & H. Chemicals Dept.

Oxides
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Metal & Thermit Corp.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
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Pins
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Louthan Mfg. Co.
Potters Supply Co.

Pins (Tile Setter)
Louthan Mfg. Co.

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Ransome Concrete Machinery Co.

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United Clay Mines Co.

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Frazier-Simplex, Inc.

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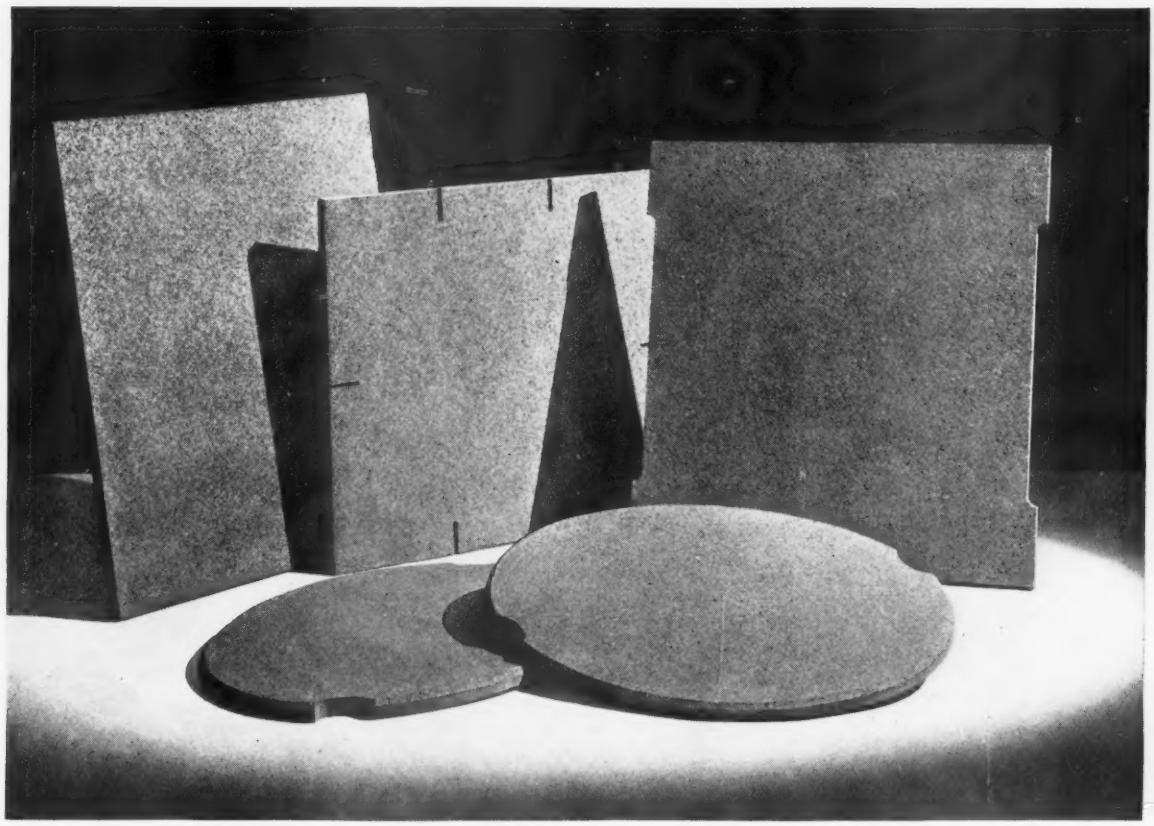
Ceramic Color & Chemical Mfg. Co.
Hardinge Company, Inc.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Porcelain Enamels
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Potters Wheels
Denver Fire Clay Co.

Potash (Carbonate)
Ceramic Color & Chemical Mfg. Co.



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Montgomery Porcelain Products Co.

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McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
Norton Co.

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Pyrometer Instrument Co.

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Lancaster Iron Works, Inc.

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Refractories
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Corhart Refractories Co.
Denver Fire Clay Co.
Louthan Mfg. Co.
Norton Co.

Refractory Materials
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Corhart Refractories Co.
Denver Fire Clay Co.
Louthan Mfg. Co.
Norton Co.
Titanium Allo & Mfg. Co.

Respirators
The DeVilbiss Co.
Drakenfeld, B. F., & Co.
The Hommel Co., O., Inc.

Rutile
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Edgar Plastic Kaolin Co.
Foote Mineral Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal and Thermit Corp.
Titanium Alloy & Mfg Co.
The Vitro Mfg. Co.

Saggers
Carborundum Co
Norton Co.
Potters Supply Co.

Salt Cake
American Potash & Chemical Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Pennsylvania Salt Mfg. Co.

Sandblast Sand
Great Lakes Foundry Sand Co.

Sand Grinder and Sifters
Lancaster Iron Works, Inc.

Saponin
The Hommel Co., O., Inc.

Screening and Magnetic Separators
National Engineering Co.

Selenite of Sodium
Drakenfeld, B. F., & Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Selenium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
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Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

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Sheets (Enameling Iron)
American Rolling Mill Co.
Bethlehem Steel Co.

Silica (Fused)
Edgar Plastic Kaolin Co.
The Hommel Co., O., Inc.

Silicate of Soda
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co
Harshaw Chemical Co.
The Hommel Co., O., Inc.

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Carborundum Co.
Norton Co.

Silicon Carbide Firesand
Carborundum Co.

Sillimanite Refractories
Denver Fire Clay Co.

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Ingram-Richardson Mfg. Co. of Indiana, Inc.
Norton Co.

Soda Ash
American Potash and Chemical Corp.
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Pennsylvania Salt Mfg. Co.
Solvay Sales Corp.
The Vitro Mfg. Co.

Sodium Antimonate
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Sodium Fluoride
Ceramic Color & Chemical Mfg. Co.
Denver Fire Clay Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Sodium Metasilicate
Harshaw Chemical Co.

Sodium Nitrite
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Sodium Silica Fluoride
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co. Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Sodium Uranate
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Soot Blowers
Frazier-Simplex, Inc.

Special Machines
Frazier-Simplex, Inc.

Spar
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Harshaw Chemical Co.
The Hommel Co., O., Inc.
Maxson, Elwyn L.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Spray Booths
The DeVilbiss Co.
The Hommel Co., O., Inc.

Spraying Equipment
The DeVilbiss Co.
The Hommel Co., O., Inc.

Spurs
Louthan Mfg. Co.
Potters Supply Co.

Stacks
Lancaster Iron Works, Inc.

Steel Plate Construction
Bethlehem Steel Co.
Lancaster Iron Works, Inc.

Stilts
The Hommel Co., O., Inc.
Louthan Mfg. Co.
Potters Supply Co.

Sulfuric Acid
Denver Fire Clay Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Pennsylvania Salt Mfg. Co.

Talc
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.

Tanks
Frazier-Simplex, Inc.

Tank Blocks
Corhart Refractories Co.

Tanks (Pickle)
The Hommel Co., O., Inc.

Tanks for Raw Material Steel or Concrete
Bethlehem Steel Co.
Lancaster Iron Works, Inc.

Tile (Floor)
Norton Co.

Tile (Muffle)
Carborundum Co.
Norton Co.

Tile Setter Pins
Louthan Mfg. Co.

Tile (Refractory)
Carborundum Co. (*Carbofrax*)
Denver Fire Clay Co.
Norton Co.

Tile (Wall)
Denver Fire Clay Co.

Tin Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
The Vitro Mfg. Co.

Titanium
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Titanium Oxide
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Trisodium Phosphate
Harshaw Chemical Co.

Trucks
Lancaster Iron Works, Inc.

Tubes (Insulating)
Carborundum Co.
Louthan Mfg. Co.
McDanel Refractory Porcelain Co.
Norton Co.

Tubes (Pyrometer)
Carborundum Co.
Denver Fire Clay Co.
McDanel Refractory Porcelain Co.
Montgomery Porcelain Products Co.
Norton Co.

Uranium Oxide
Drakenfeld, B. F., & Co.
Harshaw Chemical Co.
The Hommel Co., O., Inc.

Uranium Oxide (Yellow-Orange-Black)
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Water Softening Plants
Frazier-Simplex, Inc.

Wet Enamel
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The Hommel Co., O., Inc.
Ingram-Richardson Mfg. Co. of Indiana, Inc.
Porcelain Enamel and Mfg. Co.
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The Vitro Mfg. Co.

Whiting
Ceramic Color & Chemical Mfg. Co.
Drakenfeld, B. F., & Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Hammill & Gillespie, Inc.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Paper Makers Importing Co.
The Vitro Mfg. Co.

Winding Drums
Lancaster Iron Works, Inc.

Zinc Oxide
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
The Vitro Mfg. Co.

Zircon
Edgar Plastic Kaolin Co.
Foote Mineral Co.
The Hommel Co., O., Inc.

Zirconia
Ceramic Color & Chemical Mfg. Co.
Du Pont de Nemours, E. I., & Co., Inc., R. & H. Chemicals Dept.
Harshaw Chemical Co.
The Hommel Co., O., Inc.
Metal & Thermit Corp.
Titanium Alloy & Mfg. Co.
The Vitro Mfg. Co.

Zirconium Oxide
Foote Mineral Co.
The Hommel Co., O., Inc.

Zirkite (Natural ZrO_2)
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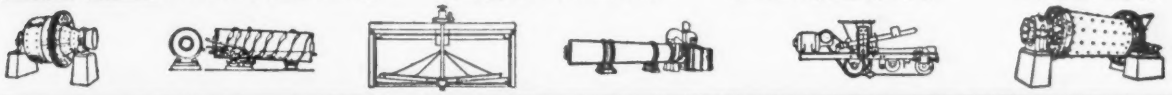

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Ceramic Specialists SINCE 1901

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SETTER RINGS
TILE SETTER PINS
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PINS : STILTS
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THE LOUTHAN MANUFACTURING COMPANY
NEW YORK EAST LIVERPOOL, OHIO, U. S. A. LOS ANGELES

"CONTROLLED MIXING"

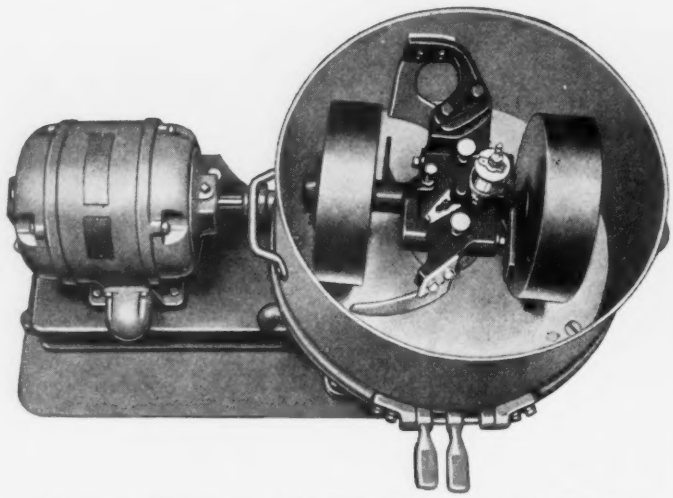
of ceramic bodies
by mulling in the

SIMPSON INTENSIVE MIXER

Progressive plants in all branches of the ceramic and refractory industries are securing important advantages and major production economies with inexpensive, flexible and closely controlled procedures in the preparation of their materials for forming.

It will pay you to investigate "controlled mixing" for your products, with the genuine muller-type Simpson Intensive Mixer recommended for this work.

Our Ceramic Engineer is available on request and will be glad to discuss your special requirements thoroughly and without obligation.



Laboratory size Simpson Intensive Mixer, equipped with removable crib, crosshead and mullers. The standard machine for test and control work on ceramic and refractory materials.

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For the British Possessions, excluding Canada and Australia—August's Limited, Halifax, England
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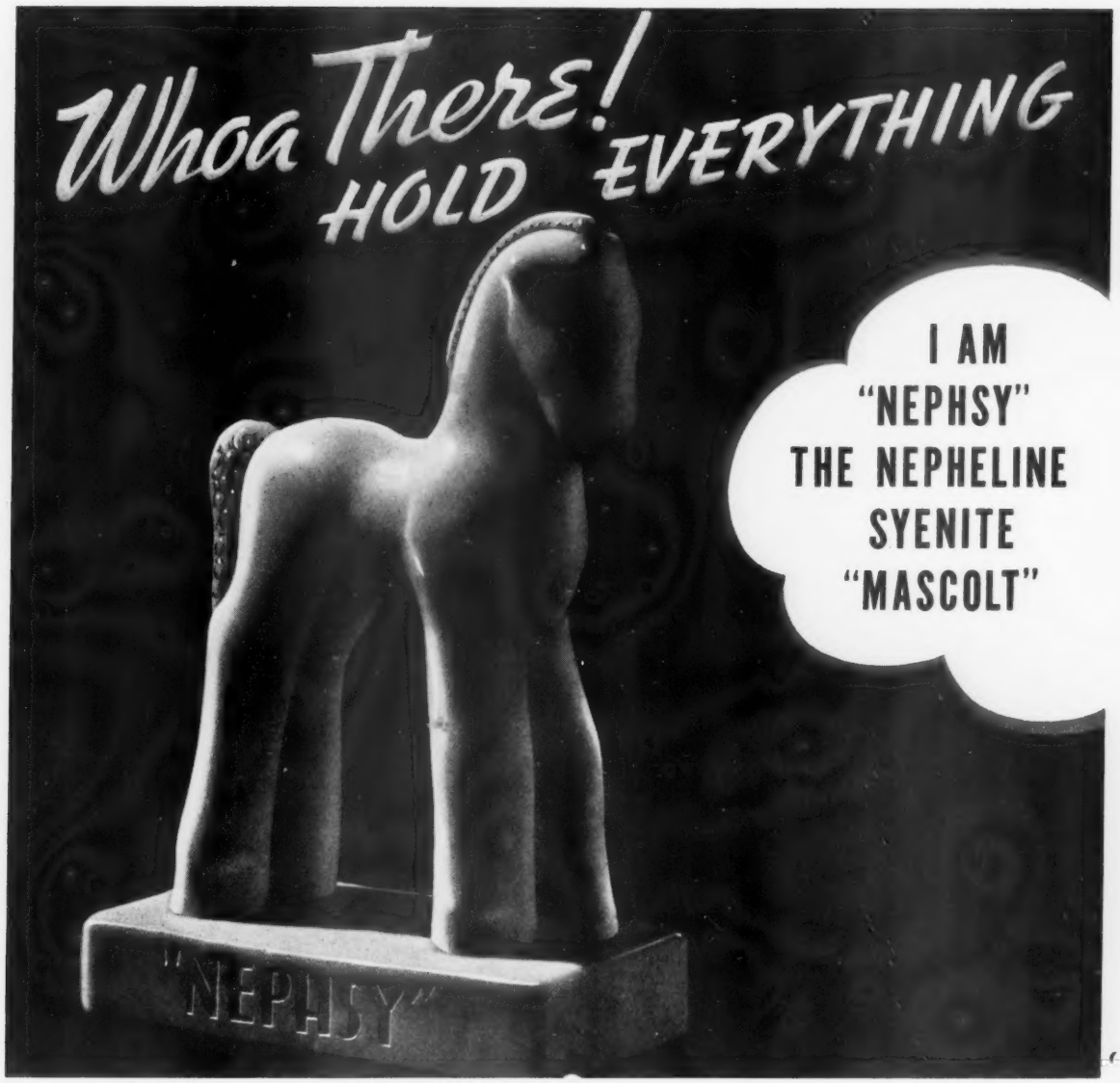

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In the manufacture of glass and enamel, Nepheline Syenite permits an increase in the aluminum oxide content without any increase in melting or firing temperatures.

All ceramists will apppreciate the low iron oxide content of Lakefield Nepheline Syenite. Its dependable uniformity eliminates possibility of trouble due to batch variations. Prompt shipments.

Great Lakes
FOUNDRY SAND COMPANY — DETROIT
CERAMIC DIVISION

HIGH ALUMINA CONTENT • IDEAL FLUXING PROPERTIES

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All Types of Circular and Straight Tunnel Kilns

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ADVERTISE IN PROGRAM

The April Bulletin will be our Forty-Second Annual Meeting Program issue.

NOTE: The copy due date will be March 1 instead of March 21, the usual copy due date.

Please make your space reservations immediately and send copy to this office by March 1.

Number of Insertions

	1 month	*3 months*	*6 months*	*12 months*
Full page	**$66.00**	**$60.00**	**$52.00**	**$44.00**
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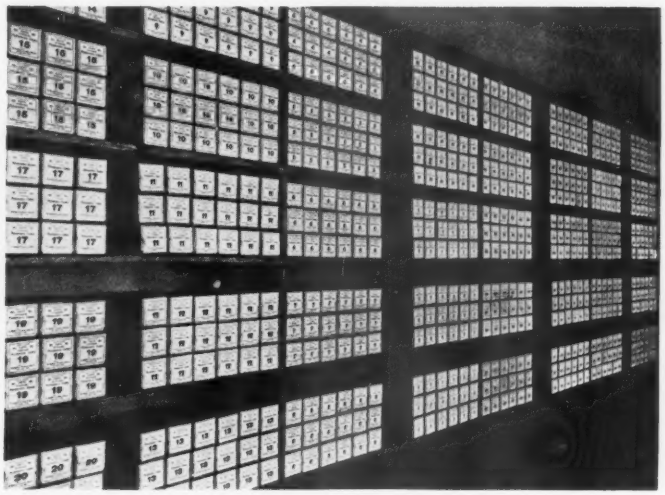
AMERICAN CERAMIC SOCIETY

2525 N. HIGH ST. COLUMBUS, OHIO

THE EDWARD ORTON, JR., CERAMIC FOUNDATION

FORTY-FOUR YEARS STANDARD PYROMETRIC CONE MAKING



Stock of Standard Cones. These cones are kept under the supervision of the research department and are used solely for standardizing the commercial cones.

FOUNDATION FELLOWSHIPS

The following are the fellowships for the present school year:

(1) *Rutgers University:* James M. Humphreys, "Association in Soda-Borosilicate Glass as Revealed by Measurements of the Dielectric Constants."

(2) *University of Illinois:* M. Kenneth Blanchard, "Glaze Slip Control."

(3) *Pennsylvania State College:* William A. Scholes, "Froth Flotation to Remove the Iron-Bearing Minerals from Clays."

(4) *Ohio State University:* Jo M. Teague, Jr., "Flux Constituent of Vitreous Whiteware Bodies."

Elwyn L. Maxson,
112 W. 9th St., Los Angeles,
Pacific Coast Representative

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Technical Ceramics

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CHATTANOOGA, TENN.

FOR SALE: Abstracts compiled by J. H. and C. J. Koenig of all articles on colors and stains and on whiteware in the 19 volumes of the *Transactions of The American Ceramic Society.* Colors, glazes, and stains abstracts (36 pages), $1.00. Whiteware (96 pages), $2.00. Address Keramos, Lord Hall, Ohio State University, Columbus, Ohio.

"CERAMIC" COLORS *For Satisfaction in Production*

COLORS

For Enamels:—Colors and Oxides; Smelter Oxides; Graining, Printing, Banding, and Screening Colors.

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For Glass:—Enamels; Vitrifiable Colors for Banding, Spraying, and Screening; Printing Colors; Fluxes; Batch Colors.

Decorating Supplies:—Printing Tissue; Screening Oils, French Fat Oil, Oil of Copaiba, Balsam Fir, Damar Varnish; Brushes; Knives and Spatulas; Grinding Mills.

CHEMICALS

Aluminum Hydrate
Ammonium Carbonate
Antimony Oxide
Antimony, Black Needle
Barium Carbonate
Barium Chromate
Bone Ash
Cadmium Carbonate
Cadmium Oxide
Cadmium Sulphide
Calcspar
Chrome Oxide, Green
Clay, Vallendar
Cobalt Oxide, Black
Cobalt Sulphate
Copper Oxides
Iron Chromate
Iron Oxides
Kryolith
Lead Chromate
Magnesium Carbonate
Manganese Dioxide
Nickel Oxide, Black
Nickel Oxide, Gray
Nickel Sulphate
Potassium Bichromate
Potassium Nitrate
Potassium Permanganate
Powder Blue
Rutile, Powdered
Selenium
Sodium Aluminate
Sodium Antimonate
Sodium Bichromate
Sodium Silicate
Sodium Silico Fluoride
Sodium Uranate
Tin Oxide
Titanium Oxide
Uranium Oxide, Orange
Uranium Oxide, Yellow
Zirconium Oxide

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Tile for Decorating Kilns

We Sell—

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Bitstone—all sizes
Fire Brick
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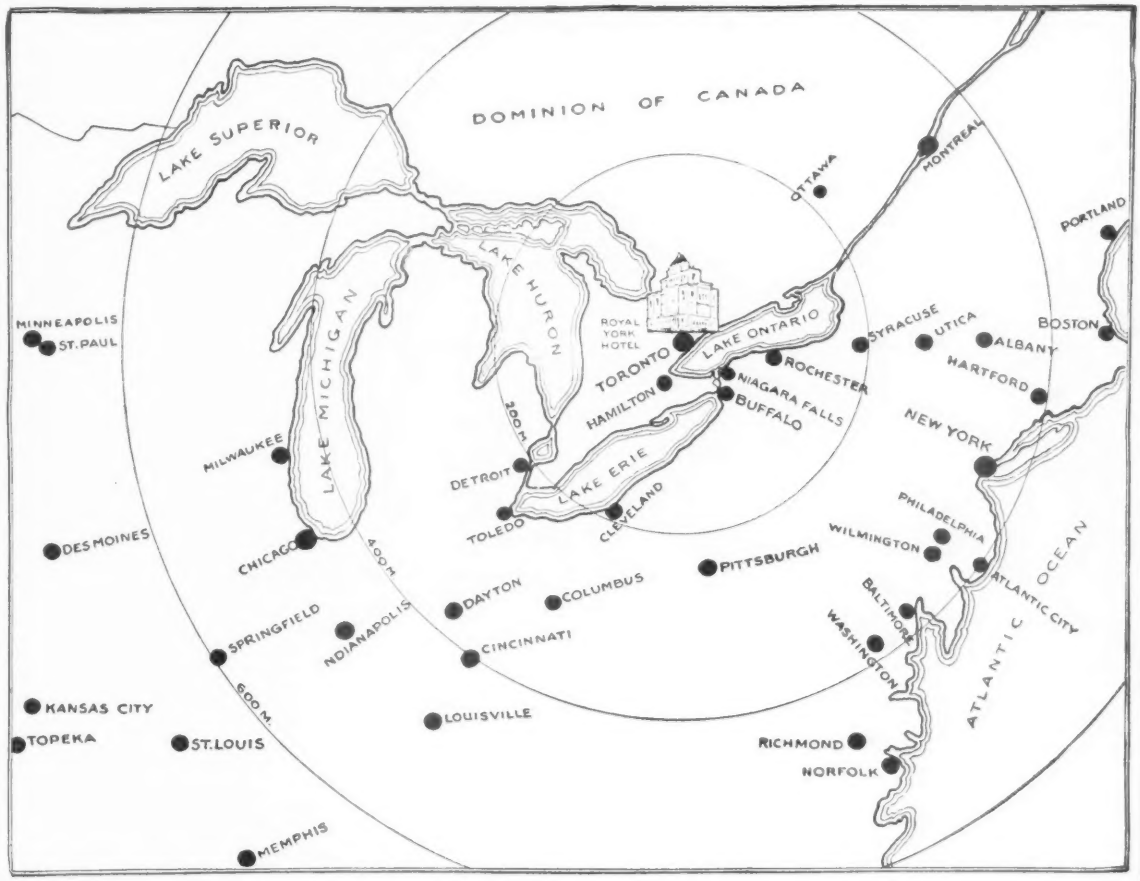
THE POTTERS SUPPLY COMPANY

EAST LIVERPOOL, OHIO

TORONTO IN APRIL
FORTY-SECOND ANNUAL MEETING
WEEK OF APRIL 7

UNUSUAL INFORMATIVE PROGRAM OF RESEARCH REPORTS



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The Royal York Hotel, the largest in the British Empire and one of the most palatial in the world, is one of the chain of Canadian Pacific hotels which stretches from the Atlantic to the Pacific. It was built and opened in June, 1929. Located in the heart of downtown Toronto, it commands a magnificent view of Lake Ontario and the lake front. A private subway connects the hotel with the Union Station where railway lines from all parts of Canada and the United States converge. From the point of view of convenience and scenic attraction, therefore, the hotel is admirably situated.

GOOD TRAINS—GOOD ROADS—GOOD AIR LANES

INFORMATION FOR U. S. EXHIBITORS AT TORONTO MEETING

(1) Exhibitors should address their shipments as follows:

American Ceramic Society Annual Meeting
For .....(name of exhibitor)
c/o Bertram & Cumming, Customs Brokers,
159 Bay St.,
Toronto, Canada

(2) Invoices (in triplicate) and bills of lading must be mailed immediately on shipment to Bertram & Cumming. Invoices must be made in triplicate, showing the Fair Market value, and be certified with the signature of the shipper. *Do not attach invoices to shipment.*

(3) Shipments should be timed to arrive several days before the Meeting date, to allow reasonable time for customs entry and delivery.

(4) Invoices should show the number and kind of packages, and each article should be itemized and the true value shown.

(5) There is no duty on exhibits being shipped into Canada from the United States for exhibition purposes, or returning to the United States. There *is* duty on advertising matter, samples, souvenirs, etc., but if arrangements are made with the Toronto Convention & Tourist Association they will assume any duty imposed.

(6) Advertising matter and material which is to be distributed free must be shipped separately and invoiced separately from goods which are for exhibition purposes only. All printed matter must be marked "Printed in U. S. A.," and invoices for such material must show net weight as well as the value.

(7) Brokers' fees, cartage, express, freight, and demurrage charges must be paid by the shipper. *All shipments must be prepaid.*

(8) Shipments must be returned to the United States in the original number of packages shipped to Canada. Should any equipment be sold while on exhibition, to remain in Canada, the purchaser must pay the duty.

(9) Exhibitors should furnish the official customs brokers, Bertram & Cumming, with an affidavit on U. S. Customs Form No. 3311, in order that free entry into the United States may be facilitated.

(10) Exhibitors should ship by rail freight or express, prepaid. If, however, exhibits are to be taken by private automobile, the Canadian Customs Form A-8 must be signed at the Port of Entry. This will permit proceeding to Toronto, where the exhibitor must report to the Canadian Customs officer.

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BALL, SAGGER AND WAD CLAY

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Dear Pete:

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Don't worry about the weather. We have an ample supply of clay in the sheds and the cars are leaving every day loaded with the same controlled uniform good ball clay.

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